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REPORT ON EFFLUENT DISPOSAL CONSIDERATIONS IN POSSIBLE PULP AND PAPER MILL DEVELOPMENTS IN SOUTHEASTERN MISSOURI

Public Health Service
Washington, D. C.

1960

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Prepared By The

U. S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service
Water Supply and Pollution Control Division

In Cooperation With The

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State of Missouri

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Figure 1. Round Spring, Shannon County, Missouri. Typical of many springs tributary to streams studied in the Ozark Region of Southeastern Missouri.

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REPORT ON
EFFLUENT DISPOSAL CONSIDERATIONS IN POSSIBLE PULP AND PAPER MILL DEVELOPMENTS IN SOUTHEASTERN MISSOURI

This report sets forth information obtained in a preliminary effluent disposal study of certain river basin areas which have been suggested as possible locations for pulp and paper mills in the southeastern portion of the State of Missouri. The river basins involved in the study were Gasconade, Current, Black, St. Francis, Big, and Meramec Rivers and the portion of the Mississippi River from Sainte Genevieve to New Madrid, Missouri. The reconnaissance survey of potential mill sites was made in keeping with the request and interest shown by the Missouri Water Pollution Board and other State and Federal agencies. Principal areas considered were:

(1) Gasconade River near Rich Fountain
(2) Gasconade River near Jerome
(3) Current-Jacks Fork Rivers near Eminence
(4) Current River near Van Buren
(5) Current River near Doniphan
(6) Black River near Poplar Bluff
(7) St. Francis River near Fisk
(8) Mississippi River -
    (a) New Madrid, (b) Birds Point, (c) Cape Giradeau
    (d) Sainte Genevieve areas
(9) Big River near Leadwood
(10) Meramec River - Steelville to St. Clair Section

The State of Missouri Conservation Commission and the Forest Service, U.S. Department of Agriculture, have conducted extensive studies in appraising timber resources that might be available for pulping in southeastern Missouri. The water and wastes disposal considerations, however, were the primary basis for this reconnaissance survey. The field work was conducted with representatives of the Missouri Water Pollution Board, Missouri Conservation Commission, Forest Service Rolla Office, U.S. Department of Agriculture, and Public Health Service, Region VI, U.S. Department of Health, Education, and Welfare. During and subsequent to the field work, considerable data and information have been furnished by a number of individuals and agencies, which have been very helpful in studies conducted in preparation of this report. The findings from the survey are briefly as follows:

Summary and Conclusions

1. Extensive timber resources exist in Missouri, particularly in the South and Southeastern portion, or Ozark region, of the State. Forest land in the Eastern Ozarks, now predominantly covered by hardwoods, comprises about three-fourths of the land area. Increasing demands for pulp and paper products and technological developments in recent years have resulted in marked increase in pulping of hardwoods. This has brought forest resources in Missouri under active consideration for pulp and paper production. In considering possible sites for mills, water needs and extent of pollution of the streams by wastes from such mills is an important factor requiring careful attention.

2. Application of modern forest management in the eastern Ozarks, is not only tending to better timber production and quality, but has resulted in almost doubling the growth stock of softwoods over the past twelve years--a noteworthy trend as regards future supply of pulpwood. In the Mississippi River border area there are substantial amounts of cottonwood and other so-called soft hardwoods, which are relatively fast growing and a good source of pulpwood.

3. Consideration of pulpwood resources in relation to potential pulping processes at mills in Missouri, indicates hardwood sulphate, or kraft, pulping, along with neutral sulfite semi-chemical, cold soda, and other of the more recent processes for pulping hardwoods will be employed. Chemi-groundwood and groundwood pulping will be utilized at such mills. Although other type mills may be considered in the future, this survey or study is limited to generally evaluating the pollution effects of the processes mentioned.

4. The introduction of pulp mill wastes into a stream will have some effect on the character or quality of the water in it. Unless adequately controlled, their impact on a stream may include removal of dissolved oxygen, fiber bottom deposits, toxicities to fish and fish foods, color, tastes and odors, foaming, and stimulation of Sphaerotilus growths. The important consideration is whether such changes as may occur will adversely affect existing and future desirable uses of the stream below the pulp mill and the extent or degree of any detrimental effects on such water uses.

5. It is expected that the minimum size mill to be established would have a capacity of 50 tons of pulp per day. Economic and other factors might indicate need for more than doubling this output. Furthermore, since semi-chemical and groundwood pulps should not be allowed to dry before conversion into paper products, such pulping processes generally will be integrated with paper manufacture. In this study it is assumed mills constructed will employ modern methods for keeping waste loads at a minimum.

6. Suitable effluent diffusion facilities will be essential to assure effective mixing of mill used waters with stream flow. In addition, protection of streams against overloads can be provided by installation of suitable facilities to enable regulated discharge during periods of low streamflow.

7. Such analytical work as performed during the field work involved in this study indicated most waters were at or near saturation for dissolved oxygen at the prevailing temperatures; with stream conditions observed being generally favorable as regards existing water quality.

8. It was evident from the study that there is very limited basic water quality data for the streams in Missouri. There is need for a comprehensive program to supply this necessary water quality information.

9. Water quality objectives have been developed and adopted January 7, 1954, by the Engineering Section of the Missouri Basin Health Council, for use as a guide for the pollution control program along the Missouri River. Other such objectives are being utilized along the Mississippi River. These guides, copies appended, have been employed by the State of Missouri in the development of its part of comprehensive pollution control activities for these particular rivers, and have been used as fundamental information in preparing this report.

10. There are a number of other factors besides water resources to meet mill needs that will require careful analysis before proceeding with possible pulp and paper developments. Considerations such as possibilities of atmospheric odor problems developing need to be given attention, with proximity to residential areas and factors that influence the strength and direction of travel of plant odors being studied in relation to suitable control methods.

7

11. Data and information regarding allowable mill capacities in areas along streams included in this study have been prepared on the premises and limitations set forth in this report, and should be considered only in accordance with this information:

    a. The Gasconade River near Rich Fountain, Missouri can support a 90-ton-per-day semi-chemical, or hardwood kraft, pulp mill, with chemical recovery system, and integrated paper production;

    b. The Gasconade River near Jerome, Missouri, has adequate water resources to provide for an 80-ton-per-day semi-chemical, or hardwood kraft mill, with chemical recovery, and conversion of pulp to paper products.

    c. The water resources of the Current River in (1) the sector from below the mouth of Jacks Fork near Eminence, to Van Buren, Missouri, could take care of the needs of a 120-ton-per-day semi-chemical, or integrated hardwood kraft pulp mill, with chemical recovery system, and paper production; or (2) the sector from below Van Buren and Big Spring to the vicinity of Doniphan, Missouri, could take care of requirements for a 240-ton-per-day pulp and paper mill employing the above hardwood pulping processes. Existing and proposed park and recreational developments in the scenic Current River Valley augur strongly against mill developments in this area.

    d. Near Poplar Bluff, Missouri, on the Black River, it would be practical to build a 65-ton-per-day semi-chemical, or integrated hardwood kraft, pulp and paper mill.

    e. The St. Francis River in the vicinity of Fisk, Missouri, would have inadequate assimilative capacity to accommodate a pulp and paper mill of minimum capacity for economic operation.

    f. The Mississippi River in areas near (1) New Madrid, (2) Birds Point, (3) Cape Girardeau, and (4) Sainte Genevieve, would be able to take care of effluents from each of the processes that might be employed for pulping hardwoods found in the river border area and Eastern Ozarks, with any mill having such daily capacity as might be considered economic for installation in these areas.

g. The Big River in the Leadwood-Desoto, Missouri, sector does not have the assimilative capacity needed to absorb the effluent from a pulp and paper mill of medium economic size.

h. The Meramec River in the sector from Steelville to St. Clair is not satisfactory for receiving the effluent from a minimum economic size pulp and paper mill. Despite exceptional measures taken to minimize and treat any mill effluent, extensive recreational use of this river would make it undesirable to locate a mill along this section. Downstream from the indicated sector the river is used as the source for Kirkwood and St. Louis County water supplies.

The foregoing findings are the results of field observations and study which included (1) assembly and analysis of hydrologic and climatologic information, estimated waste discharge, and available water quality data; and (2) correlation of collected information in terms of appropriate water quality objectives, as appended. The study necessitated the evaluation of future dissolved oxygen conditions in the waters of sections of streams indicated in southeastern Missouri, forecast under low flow, warm weather conditions with indicated types of pulp and paper production with mills of 50 tons, or greater, daily capacity located along the portions of streams covered by the survey; and consideration of the anticipated effects of the effluents on other stream characteristics related to present and anticipated future uses. 1/

In any multipurpose development of water resources the aim is to make the waters increasingly useful in meeting needs, with a basic requirement generally being effective water quality management in the public interest. Quality needs of stream waters usually vary from basin to basin with the criteria applied in management practices usually being determined by the more exacting uses of the waters. Definite cognizance is taken in this study of views expressed by representatives of the State authorities participating in the survey that water quality objectives being used for the Missouri and Mississippi Rivers be considered as minimal when applied to tributaries or inland streams, such as the Gasconade, Meramec, Current and other Ozark rivers.

The importance of maintaining a high degree of cleanliness in the relatively unpolluted portions of these streams, and of providing for suitable utilization, treatment and disposal of existing and future pollutional waste is recognized. Missouri has a valuable asset in its clear, cool, spring fed streams (See Figure 1) of the Eastern Ozark region, and in the border waters of the Mississippi River. The Ozark waters are already utilized to considerable extent for the benefit and enjoyment of both the citizens and visitors to the State. Accordingly, the essential problem is to conserve to the fullest extent possible the value of these waters for all purposes.

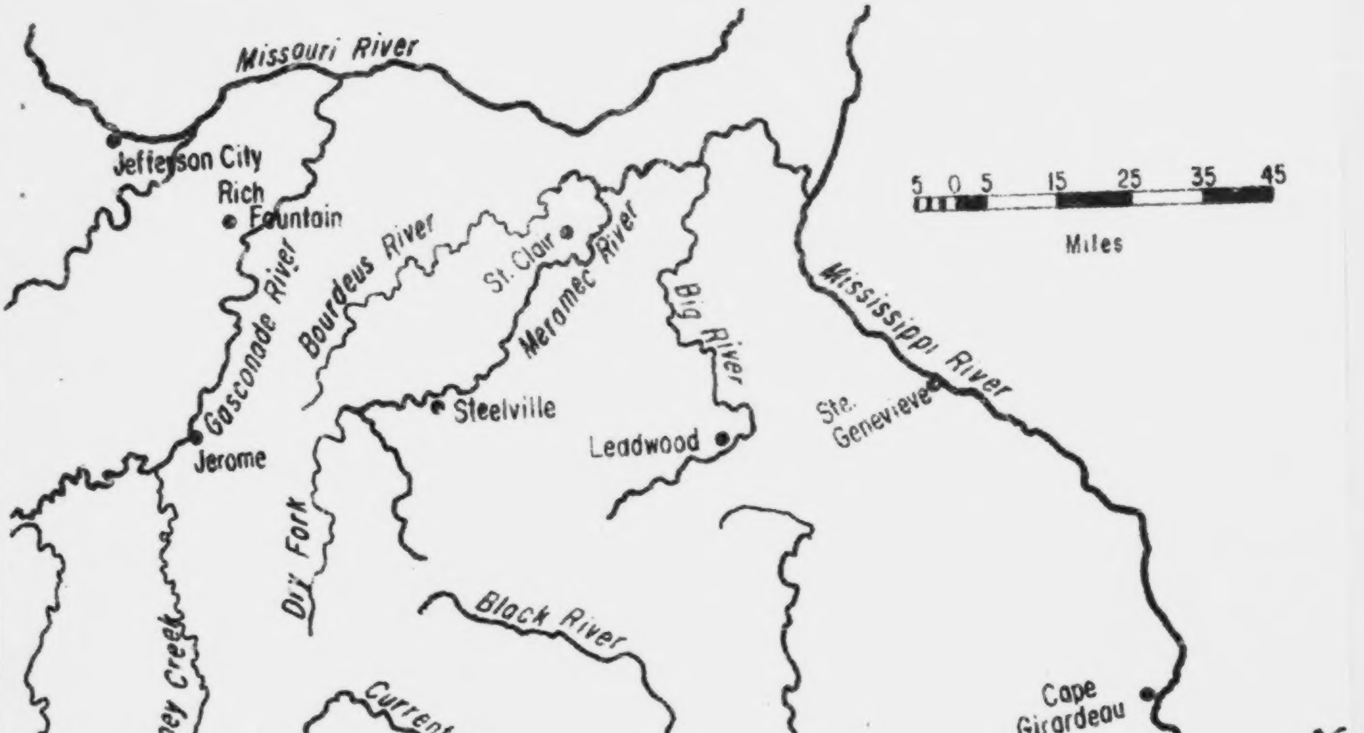
GENERAL INFORMATION

Request:

At the request of Mr. Jack K. Smith, Executive Director of the Missouri Water Pollution Board, made to the Public Health Service Region VI Office at Kansas City, Missouri, through Mr. Herbert C. Clare, Regional Program Director, Water Supply and Pollution Control, steps were taken to enlist assistance of the Sanitary Engineering Center and Washington headquarters of the Public Health Service in making a preliminary appraisal of potential pulp and paper mill sites in the southeastern part of Missouri from the point of view of water pollution. In view of prior commitments at the Center, it was finally arranged that L. F. Warrick of the headquarters staff should cooperate in such a reconnaissance survey. Readily available information was assembled and an initial conference was held on plans for the requisite field work in the Offices of the Missouri Water Pollution Board, Jefferson City, Missouri on September 19, 1960. In addition to the above individuals, there were present at the conference: Mr. C. Lewis Harrison, Supervisor, Missouri National Forest, Forestry Service, U.S. Department of Agriculture; Mr. John E. Wylie, Cooperative Forestry Engineer Supervisor; Mr. John L. Funk, Fisheries Research Supervisor, and Mr. Herbert J. Fisher, Fisheries Biologist, Missouri Conservation Commission; Mr. Edward S. Lightfoot, Chief of Design and Construction, Missouri Water Pollution Board; Dr. Joseph K. Neel, Regional Biologist; and Mr. Donald Marshall, Sanitary Engineer, Public Health Service, U.S. Department of Health, Education and Welfare Regional Office VI, Kansas City, Missouri.

During this initial conference it was indicated that interest was increasing in establishment of pulp and paper mills in Missouri, with future better utilization of the State's abundant

MAP I—RIVERS OF POTENTIAL PULP MILL AREA
IN SOUTHEASTERN MISSOURI


Missouri River
Jefferson City
Rich Fountain
Gasconade River
Bourdeus River
St. Clair
Meramec River
Big River
Mississippi River
5 0 5 15 25 35 45
Miles
Steelville
Jerome
Leadwood
Ste. Genevieve
Dry Fork
Piney Creek
Black River
Cape Girardeau
Current River
Ohio River
Jack's Fork
Eminence
Bird's Point
OZARKS
Van Buren
Ste. Francis River
Fisk
Mississippi River
Bryant Creek
Eleven Point River
Poplar Bluff
New Madrid
Doniphan
MISSOURI
ARK.
TENN.
Black River
Lake Norfolk
Spring River
White R.

timber resources. While the pulp and paper industry had previously been developed in areas where softwoods were readily available, technological developments of recent years have brought hardwood forest lands into active consideration for taking care of mounting needs for increased pulp, paper and paperboard production. Missouri, with its extensive hardwood forests and other important assets, will undoubtedly be regarded more and more favorably for location of mills in the future expansion of the pulp and paper industry in this country.

Concern has been expressed, however, that such developments take place only with all possible safeguards against detrimental effects on other valuable State assets, including the quality of the waters in areas where mills might be located. In the discussion of such areas it was agreed to devote attention to streams in the southeastern portion of the State in the reconnaissance survey, in view of extensive woodlands of the Eastern Ozarks and Mississippi River border area. The principle streams in the portion of the State to be considered are indicated on Map I. Preliminary arrangements were made at the conference to gather as much data on stream flows, water quality, existing and proposed developments in the watersheds, and other pertinent information needed for the requested study.

Purposes:

It was indicated that the purpose of the study would be to make preliminary estimates from currently available knowledge of water resources, of watershed conditions and of the nature and extent of such pollution as may be anticipated from the establishment of present processes for producing pulp and paper from hardwoods, of what size mills might be provided within the assimilative capacities for effluents of various sectors of the streams in southeastern Missouri. Adequate water of suitable quality for manufacturing purposes and dilution of effluents is quite important among factors governing mill site selection. The intent of this study is to indicate from estimates of water pollution impacts of economic size mills on the streams involved whether additional consideration and study of certain sites would be justified.

FIELD WORK

The arrangements for the field work made by the staff of the Missouri Water Pollution Board with consultation and assistance of the other interested State and Federal agencies provided for the inspection of those areas and stream sectors that might be considered as possible sites for future pulp and paper mills in southeastern Missouri. The survey involved observation of the characteristics of the streams and watershed developments at numerous locations. Sufficient dissolved oxygen determinations were made to get information on oxygen resources that could be expected under low stream flow conditions prevailing generally in the East Ozarks and Mississippi River border areas inspected during the third week in September, 1960.

Of those participating in the initial conference in Jefferson City, Messers John E. Wylie, John L. Funk, Herbert J. Fisher, C. Lewis Harrison, Edward S. Lightfoot, Herbert C. Clare, Donald Marshall and Louis F. Warrick took part in the field survey. The stream sectors along which mills might be located were inspected at conveniently accessible locations. Inquiry was made into water uses in the areas visited, covering municipal, industrial, agricultural, recreational and other interests involved. The anticipated future developments as well as existing conditions that might influence consideration of sites were reviewed. Data obtained along with that furnished by the cooperating and other official agencies provided needed background for studies included in the report.

Travel within and between watershed areas under consideration was by automobiles, making it possible to observe flow conditions at a number of locations along each of the streams involved. Particular attention was given to determining whether turbulent or quiet flow was occurring in specific reaches of the streams, to considering the influence of very substantial flows existing from big springs found in the Eastern Ozarks (Figure I), and acquiring other information needed to make estimates of the stream aeration and oxygen resources available for oxidation of such wastes as would be discharged from pulp and paper mills.

Figure 2. Extensive Ozark timber resources, mostly hardwoods, viewed from fire tower near Highway 19, north of Eminence, Missouri.

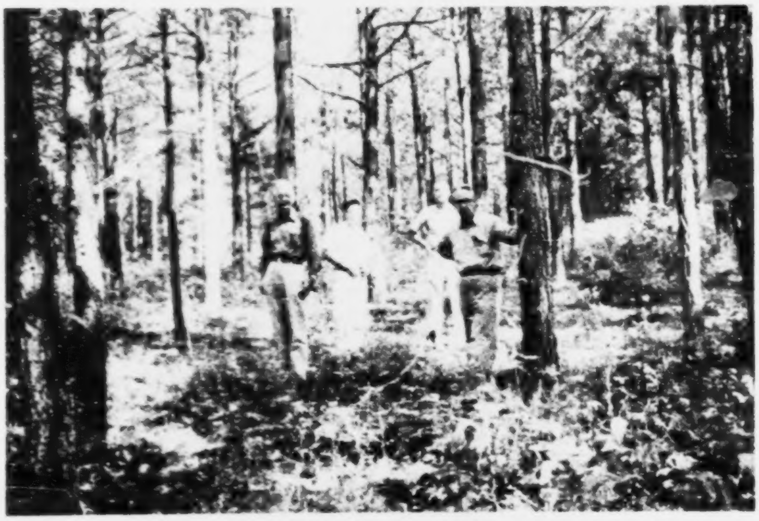
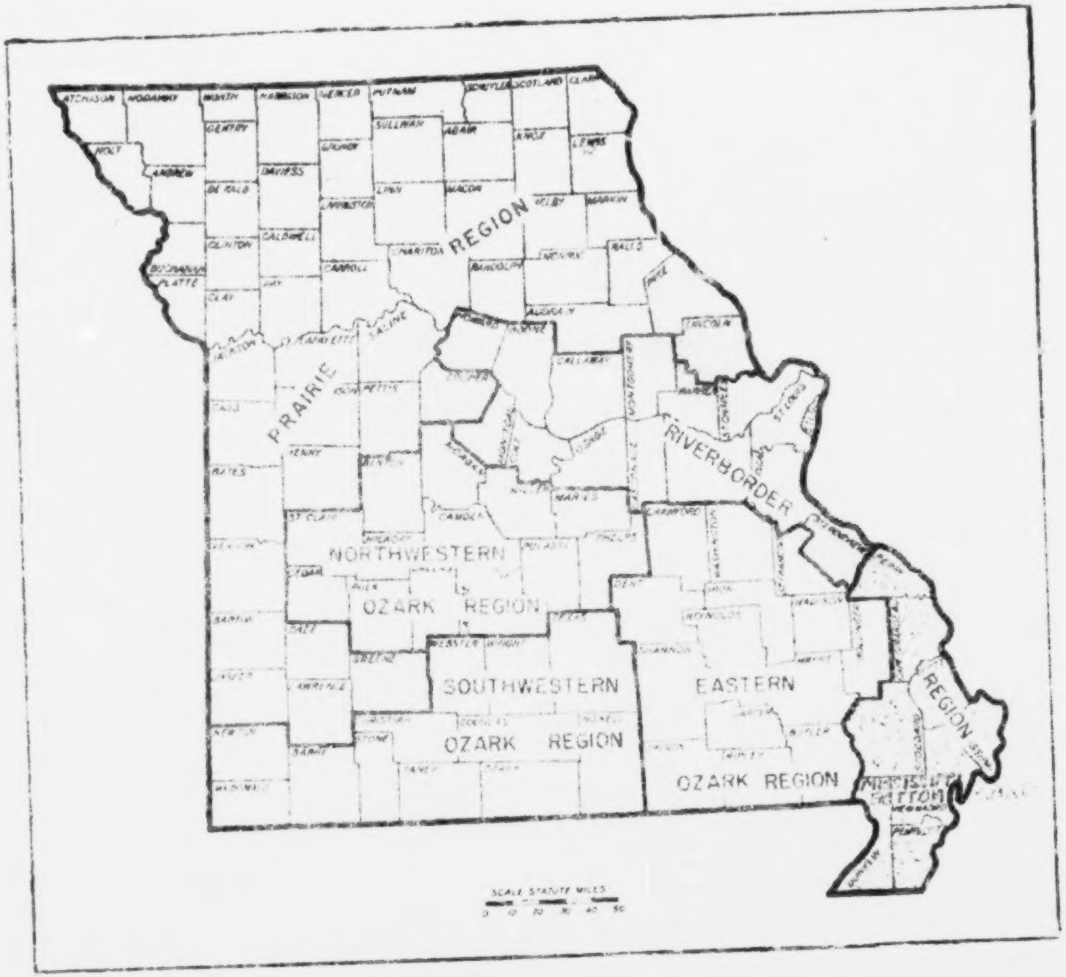


Figure 3. Modern forestry management is improving timber growth, with pine-type commercial forest acreage almost doubling since 1947 in the Eastern Ozark Region.


REGION
PRAIRIE
RIVERBORDER
NORTHWESTERN
OZARK REGION
SOUTHWESTERN
OZARK REGION
EASTERN
OZARK REGION
REGION
MISSISSIPPI BOTTOM
ATCHISON
NODAWAY
WORTH
HARRISON
MERCER
PUTNAM
SCHUYLER
SCOTLAND
CLARK
HOLT
ANDREW
GENTRY
GRUNDY
SULLIVAN
ADAIR
KNOX
LEWIS
DE KALB
DAVIESS
LINN
MACON
SHELBY
MARION
CLINTON
CALDWELL
LIVINGSTON
CHARITON
RANDOLPH
MONROE
RALLS
BUCHANAN
PLATTE
CLAY
CARROLL
PIKE
LINCOLN
JACKSON
LAFAYETTE
SALINE
CALLAWAY
CASS
PETTIS
ST. LOUIS
BATES
HENRY
ST. CLAIR
HICKORY
CAMDEN
MARIES
PHELPS
CRAWFORD
WASHINGTON
CEDAR
POLK
BARTON
DENT
REYNOLDS
SHANNON
JASPER
GREENE
WEBSTER
WRIGHT
LAWRENCE
NEWTON
CHRISTIAN
DOUGLAS
HOWELL
CARTER
BUTLER
RIPLEY
STONE
TANEY
OZARK
MCDONALD
BARRY
SCALE STATUTE MILES
0 10 20 30 40 50

Location of the Eastern Ozarks in Missouri.
MAP II

The route and sectors of streams surveyed extended southeasterly from Jefferson City covering progressively the following principal areas: (1) Gasconade River near Rich Fountain, (2) Gasconade River near Jerome, (3) Current-Jacks Fork Rivers near Eminence, (4) Current River near Van Buren, (5) Current River near Doniphan, (6) Black River near Poplar Bluff, (7) St. Francis River near Fisk, (8) Mississippi River border area including (a) New Madrid, (b) Birds Point, (c) Cape Girardeau, and (d) Sainte Genevieve areas, (9) Big River near Leadwood, and (10) the Meramec River in the St. Clair - Steelville sector. The locations of the rivers and places indicated are shown on Map I. Some of the important features of the Eastern Ozark and Mississippi River border regions and factors pertinent to the survey in Southeastern Missouri are described under the following heading.

Areas Involved:

Of all of the river basins studied, only the Gasconade River drains into the Missouri River. The remainder discharge directly or indirectly to the Mississippi River in Missouri, or discharge to it to the South through Arkansas. The portions of the Gasconade, Meramec and Big Rivers studied are located in a transitional belt existing between the rough Ozark hills in the South and the glaciated prairies of northeastern Missouri. (See Map II)

The Current, Black and St. Francis Rivers have their sources in the Eastern Ozarks, a region characterized by steep forested slopes of stoney, light-colored soils of low fertility. Taum Sauk Mountain, the highest point in Missouri, with an elevation of almost 1800 feet, or 1000 feet above the average elevation of the State, is in this region. The hilly to almost mountainous terrain has numerous deep valleys that drop as much as 700 to 800 feet below the ridges. This region is the most heavily forested portion of the State with about three fourths of its area in forest, as illustrated in Figure 2, being timbered predominantly with second-growth stands of oaks and a mixture of other hardwoods. Some shortleaf pine is growing in this area.

Application of modern forest management in the eastern Ozarks, is not only tending to better timber production and quality, but has resulted in almost doubling the growth stock of softwoods over the past twelve years--a noteworthy trend as regards future supply of pulpwood (See Figure 3). In the Mississippi River border area there are substantial amounts of cottonwood and other so-called soft hardwoods, which are relatively fast growing and a good source of pulpwood.

The Mississippi River Border region, and particularly the area extending South of Ste. Genevieve County along the river to the Missouri-Arkansas Stateline that has been designated as the Mississippi Bottomlands, differs greatly from the Ozark region to the West. In general, the topography varies from slightly hilly to an almost flat allurial plain, with the roughest portions along the rivers in Ste. Genevieve and Jefferson Counties. These bottomlands of southeastern Missouri constitute the northern tip of the broad flat expanse of poorly drained plain extending North from the mouth of the Mississippi River. The average altitude of this region in Missouri varies from 300 feet in the South to 350 feet in the North, and the few low ridges have elevations of only 30 to 160 feet above the general plain. The rich soil of the bottomlands is of complex origin, being made up of materials deposited by the rivers.

Unlike the Eastern Ozarks with its wide expanse of timberland including National and State Forests and outdoor recreation areas, the more populated Mississippi bottomlands are largely used for agriculture, and allied industries. While crops are least significant as a source of cash farm income in the Ozark region, the opposite situation generally applies in the eight southeastern Missouri Counties comprising the bottomlands, as shown on Map II.

Cotton, tobacco, soybeans, corn and vegetables are grown extensively in the delta lowlands, while more wheat and grain is produced in the northern four counties of this area. In these counties are found most of the livestock farms, although hogs, chickens and some dairy animals are produced throughout the Mississippi bottomlands.

The fact that the major portion of the land area in this region is now in farms is due in part to an extensive, intricate system of drainage canals. Drainage will be mentioned later in the discussion of water resources of each region. While a considerable part of farm acreage is devoted to the raising of crops, there are good stands of timber in some of the farm woodlands, and particularly in those areas between levees and the river. The fertile soils, high water table and long growing season were initially responsible for heavy stands of timber, such as oak, elm, sweetgum, cypress, hickory, pecan, yellow poplar and cottonwood.

The rapid-growing cottonwood has mounted increasingly in importance as a source of pulpwood. It requires abundant soil moisture. The moisture is quite necessary for the germination of

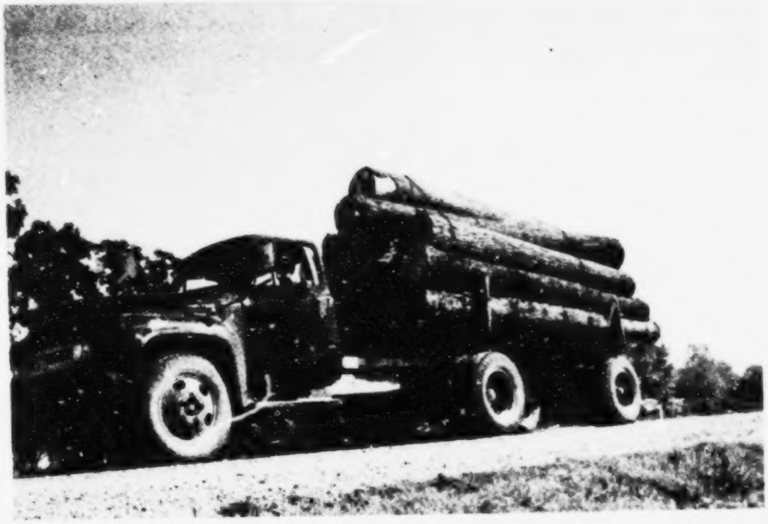


Figure 4. Sawtimber is usually hauled to sawmills by trucks.

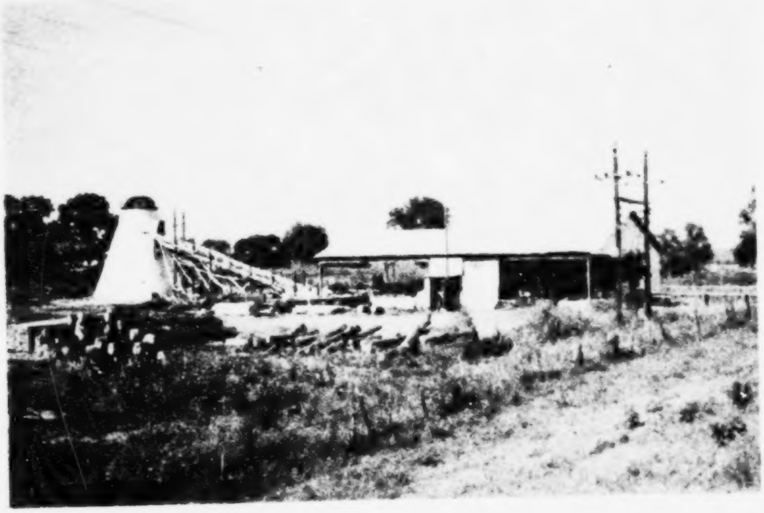


Figure 5. A small sawmill of the type now being operated in Southeastern Missouri.

cottonwood seed. Warmth and sunlight are important to its development. With an average annual rainfall of over 50 inches and frost-free periods of 210 days or more each year, conditions found in the Mississippi bottomlands of Missouri are particularly favorable for producing such trees. Accordingly, substantial portions of the low lying, occasionally inundated, areas along the river are now covered with heavy stands of cottonwood.

Farm woodlands are being more widely recognized as furnishing a sizable contribution to the farm economy. Aside from the fuelwood, lumber, fence posts, and miscelaneous timber items produced and consumed on the farms, timber is being more and more treated as a profitable crop with interest being shown in applying better forest practices.

Missouri has a good system of trunk highways and farm to market roads. This highway system, with a considerable portion of county roads being of all weather construction, is quite important in transporting forest products. Sawlogs are hauled to many of the sawmills, and forest products in large quantities are transported to market, solely by truck. (See Figures 4 and 5). Railway facilities provide transportation for a substantial tonnage of forest products. Logging operations, however, usually do not concentrate a large enough volume of logs and bolts to justify railroad logging. The major portion of forest material tonnage shipped by rail is first conveyed to shipping points by truck.

Rivers in or bordering Missouri offer another means for transporting forest materials. Over 1000 miles of the streams are classed as navigable waterways. In the southeastern portion of the State under study, however, the major waterway considered of special importance for purposes of transportation of forest materials including pulpwood is the Mississippi River.

The percentage of forested areas increase in proceeding North through Cape Girardeau, Perry and Ste. Genevieve Counties, with the first two being reported as 15 to 30% wooded, and the latter having over 45% forest cover. Ste. Genevieve County, situated along the Mississippi River and immediately adjacent to the Eastern Ozarks, is indicated to be the most heavily wooded areas of the Mississippi-Missouri River Border Region.

The general forest types in Ste. Genevieve and other counties involved in this study in this region as far West as Osage County vary from bottomland hardwoods along streams to oak-hickory to oak-pine types characteristic of the Eastern Ozarks in the uplands. Good stands of oak, elm, hickory, sycamore, cottonwood and other hardwoods, as well as some red cedar and shortleaf pine were observed in this area. The field studies included a visit to the tree farm of the State of Missouri in the Meramec Park area in Franklin County, where various conifers or species of trees best suited for stocking purposes are being determined. This is an important part of the outstanding activities in Missouri to improve the quality of forestry resources through development and use of modern practices in forest management.

Forest-products industries in both the Eastern Ozarks and Mississippi-Missouri River Border Region, include principally those supplying primary forest products, such as rough lumber, cooperage stock, mine timbers, fuelwood, fence posts and similar materials, and those processing the primary materials into secondary forest products such as sawn lumber, cross ties, staves, veneer, handles and containers.

Recent studies of the University of Missouri, Agricultural Experiment Station, in cooperation with the Central States Forest Experiment Station and the Lake States Experiment Station, Forest Service, U.S. Department of Agriculture, comparing results of surveys of 1947 and 1959, have shown definite improvement trends in the commercial forest area of the Eastern Ozarks.* Of particular interest is the fact that production of pine type timber has practically doubled during the twelve year period. This increased softwood resource is significant as regards the potential future supply of pulpwood from southeastern Missouri.

PULPWOOD PRODUCTION

There are no pulp and paper mills in the State, and such small amounts of pulpwood as produced in the past have been shipped to mills out of State. The ever increasing demand for pulp, paper and paperboard along with technical developments in the industry, have increased greatly the possibilities for such mills being installed in Missouri.

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* Unpublished data, 1960

In an article entitled "Pulpwood in the Missouri Ozarks", appearing in the June, 1960 issue of the Missouri Conservationist, Mr. George O. White* states as follows:

"During the past few years, there has been a considerable change in the use of wood for pulping purposes. Long fibered soft woods such as spruce were originally the only woods used; later new processes were developed to use pine, and now there is a continuing growth in the use of hardwoods such as oak, cottonwood, maple, etc. Most species of hardwoods can be used for some wood fiber products, although a few species like hickory, Osage orange and black locust are seldom used. Many persons in discussing the possibility of the use of more pulpwood in Missouri have been thinking in terms of the various types of paperboard rather than paper. Paperboard is the term usually used for such products as container board, bending board, non-bending board and building board.

"Most of the companies operating pulp mills are intensely interested in promoting good forestry practices in the areas which they secure their pulpwood. Since most of the paper mills operate on a twenty-four hour a day basis they must have a continuous supply of wood over a long period and their financial investment will not permit frequent moves to follow the wood supply. This condition is the reverse of what has happened with the charcoal plants which get their wood for practically nothing from farmers who want to clear land. The result is that instead of using this outlet of low grade wood for the improvement of their woodlands, it results in the further deterioration of the woodlands and the bringing of more poor land into agriculture for a short period. Many responsible pulp mill owners on the other hand pay a premium for material which is harvested under good forestry practices and in many cases employ foresters to aid the timberland owners so that their woods will be improved by cutting rather than deteriorated.

"A pulpwood industry would be important to Missouri from the standpoint of using much wood which is now difficult to sell. Under most circimstances the higher quality trees will bring a higher price for sawlogs and veneer; so that if wood is managed for more than pulpwood alone, the returns will be greater".

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* White, George, O., Missouri Conservationist, Vol. 21, No. 6 pp. 4-5 (June, 1960)

In discussing the pulpwood production situation in relation to possible mill sites in the Ozarks, assuming a small to medium size mill of 200 tons of pulp per day, John H. Farrell*, Forest Economist, Forest Service, U.S. Department of Agriculture, pointed out in an article in the November, 1959, issue of MISSOURI BUSINESS as follows:

"There is ample raw material in the Ozarks generally for several pulp mills, considering standing timber, annual growth, and the ability of new type mills to use cull material, species formerly considered unmerchantable, and even limbs and wood chips. Can the forest in a selected locality supply the needed wood, however? Here an exact answer depends upon a specific case, but a generalization is possible.

"Most mills purchase wood within a 50-mile radius of the plant. Beyond this limit, transportation costs increase rapidly. Some mills truck wood twice this distance.

"A hypothetical circle 50 miles in radius placed almost anywhere in the region would include more than three and a half million acres of commercial forest land, 86 percent privately owned. Trees larger than 5 inches in diameter would total nearly 16 million cords of sound wood, 89 percent hardwood species. Known as the "growing stock", this is only part of the total volume on the land. Defective trees, unmerchantable species, and tops and large limb wood suitable for pulpwood but not always desired for this use, add another 14 million cords to the total supply.

"All the "growing-stock" volume (the 16 million cords) would not be available to the mill at once because under good forest management a large part of the volume would normally be left to grow. Only mature trees and undesirable trees would be removed. The volume of undesirable trees available to the plant from this source would be great during the first decade of management, tapering off as the timber stands gradually improved.

"Annual growth provides another potential supply. Forests grow a lot of wood annually, even though individual trees show only a slight increase in volume. Growth rates in the Ozarks, even on timber stands not under good forest management, indicate our sample area should produce nearly 580,000 cords of wood per year in excess of losses by normal mortality. This would support about four mills if it were all available for pulping. Under good management, Ozark forests could triple this growth production.

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*Farrell, John H., "What A Pulp Mill Could Mean To Missouri", MISSOURI BUSINESS, November, 1959

"A single industrial plant would not have all of this wood meterial solely for its own use, however. Careful study would be needed to tell if existing growth and planned timber removal under management would provide a surplus above the requirements of present wood users in the region. Information on exact quantity and quality for specific locations must come from a detailed survey such as the one now being conducted by the U.S. Forest Service in cooperation with the Missouri Conservation Commission, the University of Missouri School of Forestry, and members of the wood-using industry".

The species composition of commercial forest areas of southeastern Missouri considered for pulpwood production is of definite interest as regards pulping processes likely to be employed and effluents to be anticipated, as discussed later in this report. The 1959 forest survey* previously mentioned listed the following species of hardwoods: oak-white, post, other white, black, scarlet, northern red, and other red; hickory-shagbark, shellbark, mockernut and other hickory; maple - hard and soft; birch; black walnut; ash; elm; sweetgum and blackgum; yellow poplar; sycamore; cottonwood and some other hardwoods. The softwood species are shortleaf pine, cypress and red cedar. The oak-hickory type of forest is the most extensive type, with black oak, scarlet oak and post oak predominating in the Eastern Ozarks. The white oak is the most common species in the River Border region. There has been steady conversion of oak-pine type forest areas in the Eastern Ozarks to the pine type, which type can furnish pulpwood well suited to conventional methods of both mechanical and chemical pulping.

However, to keep the pulpwood situation in proper perspective, pine, though doubling in area occupied and in volume since the survey reported in 1947, comprise only 10 percent of the commercial forest in the Eastern Ozarks. Present markets for the pine, including poles, posts and lumber, take a large share of available trees. Therefore, there will be an insufficient local supply of pine for pulp for some time to come, and the principal supply of pulpwood must be from among the hardwood species using the special processes developed and applied in recent years for pulping hardwoods.

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*Mendel, Joseph J., "Highlights of the Timber Resources in Eastern Ozarks, Missouri" - unpublished preliminary statistics - May, 1960.

Before describing pulping processes and considering mill effluents in relation to water resources, several other considerations or trends concerned with wood supply should be mentioned. It has been stated recently by Robert A. Rolston,* Research Center Leader, Columbia Forest Research Center, Central States Forest Experiment Station, Forest Service, U.S. Department of Agriculture, as follows: "The use of hardwoods for pulp makes it possible to utilize trees that should be cut early in order to pursue good hardwood and pine management. Thinnings are needed in all of our hardwood stands to stimulate the growth of the higher quality trees. The soil will produce just so much wood fiber, and foresters have learned that it is good business to add all of the growth possible to fewer, better trees. Young pine trees stagnating in the shade of low quality hardwoods can be released to grow unfettered at a profit through a pulpwood market. Otherwise, they must be released at a cost of $2-$10 per acre through noncommercial operations.

"In addition, trees and portions of trees not suitable for lumber can be utilized for the manufacture of pulp and paper. Not that the pulp industry can use decayed wood to make paper. They can't. However, the pulping process requires chipping or grinding of the wood. This permits the use of smaller sized trees, both in diameter and length, than needed for sawlogs".

A noteworthy modern trend is preparation of wood for pulping at sites other than the location of the mill. Development of portable chippers that can cut the pulpwood into chips of suitable size for further processing and which can be operated in the forest or at locations convenient for transportation, have aided in this change. This equipment now extensively used in the northwest and increasingly throughout the southeast after being started in the Lake States area, makes possible the use of much wood that might otherwise be wasted. Wood refuse burners, such as the inverted conical type shown at the left in figure 5, become obsolete. The trim and other good pulping materials now discarded in sawmill

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*Rolston, R. A., "What A Pulp and Paper Mill Could Mean to Missouri's Forest Economy", paper presented at the Sixth Air and Water Pollution Conference, University of Missouri, Columbia Missouri, November 15, 1960.

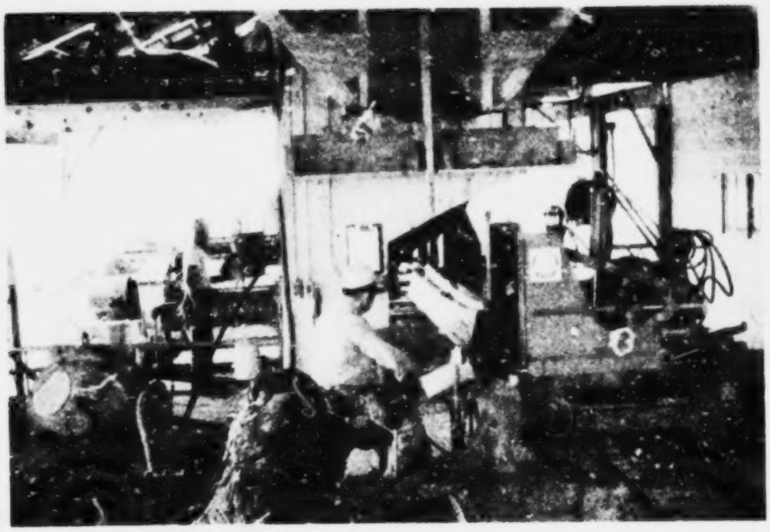


Figure 6. Modern bandsaw equipment is utilized in this sawmill.

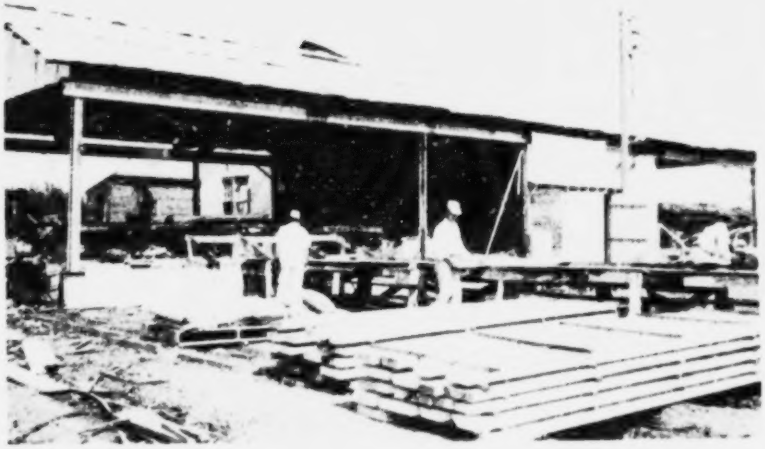


Figure 7. Lumber and added wood products, including pulp, offer increasing benefits from better use of renewable timber resources of Southeastern Missouri.

operations, such as illustrated in figures 6 and 7, can be utilized instead of burned by employing the portable chippers at such sawmills. In some instances production at some small sawmills, such as are found in the Ozarks and River Border region in Missouri, has been converted entirely to turning out chips for pulping. New installations specifically for this purpose are increasingly being reported, citing advantages of employing the new equipment and techniques in wood preparation at places other than where the pulp is produced.

PULPING PROCESSES

There are in the main four different kinds of wood pulp: mechanical pulp, sulfite pulp, sulfate pulp, and soda pulp. The first is prepared by purely mechanical means, the other three by chemical means. The mechanical pulp contains all of the wood except the bark and that lost during storage and transportation. Chemical pulps, however, are essentially pure cellulose, the unwanted and unstable lignin and the other noncellulosic components of the wood having been dissolved away by the treatment. Because of this, chemical pulps are much superior to mechanical, or groundwood pulp, for fine papermaking. However, owing to the special processing required, they are too expensive for the cheaper grades of paper, such as newsprint.

The mechanical, or groundwood, process, unless applied with special modifications to be described, is not suitable for use with most hardwoods. The sulfite process, which is mainly used on softwoods of low resin content, employs an acid chemical solution to remove the natural adhesive, or lignin, from between the wood fibers. Hardwoods are also pulped by the sulfite process for use in the better grades of paper. The hardwood sulfite pulps are generally weaker than the long fiber softwood sulfite pulps. The sulfate, or kraft, process employs an alkaline solution of sodium hydroxide and sodium sulfide. This process is applicable to pulping practically all woods, inclusive of the hardwood species in Missouri. As regards the soda process, it is only modern adaptation of the use of soda to hardwood pulping with which this report is concerned. This process is included among the chemical-mechanical treatments for the pulpwood. Three relatively new pulping technologies - the neutral sulfite semi-chemical process, the chemigroundwood and the cold caustic soda process - employ both chemical and mechanical treatments to defiber the wood.

To aid in the general understanding of waste disposal problems associated with mills employing these processes, the following description of the pulping and paper making operation is presented.

Mechanical (Groundwood) Process

The mechanical, or groundwood, process consists essentially of the continuous removal of fibrous material from the surface of wood blocks by a revolving abrasive grindstone. Water is sprayed continuously on the grindstone to cool and clean the surface as well as to act as a lubricant. The pulp collects in a pit beneath the stone and flows to a screening system.

The yield of pulp obtained by this method is well above 90 percent of the weight of the wood ground. Groundwood pulp, although much lower in strength than chemical pulps prepared from the same woods, imparts to printing papers many desirable qualities, such as bulkiness, softness, opacity, and finish.

Sulfite Process

The sulfite process for pulping wood involves "cooking" chips in a digester at high temperatures and pressures along with a solution of sulfurous acid in which lime or some other base is dissolved. The cellulose fibers are separated from lignin, hemicelluloses, and other cementing materials. Calcium bisulfite in the cooking liquor reacts with the lignin in the wood to form soluble calcium lignosulfonate. Wood gums are also hydrolyzed in the acid cooking liquor at high temperatures. The soluble materials present in the spent liquor are drained away from the fibers at the end of the cook, the liquid effluent being designated as sulfite waste liquor (SWL) or spent sulfite liquor (SSL).

Soluble products of digestion in the sulfite waste liquor comprise about 50% of the weight of the wood. For every ton of sulfite pulp, about a ton of soluble material is discharged to streams in about 2500 gallons of waste digestor liquor, more or less diluted with wash waters and other mill wastes. As normally reported, SSL contains 10% solids, mostly lignin and carbohydrates. The quantities vary according to the woods used and method of cook.

TABLE I

ESTIMATED COMPOSITION OF CALCIUM SPENT SULFITE LIQUOR

	COMPOSITION	
	Liquor Basis	Total Solids Basis
Component	(%)	(%)
Total Solids		
Lignin sulfonic acids	6.5	65.0
Fermentable sugars	(1.5)	(15.0)
Non-fermentable sugars	(0.5)	(5.0)
Total reducing sugars	2.0	20.0
Calcium (as CaO)	0.7	6.7
Other compounds	0.8	8.3
	10.0	100.0%
Water	90.0	
Calcium spent sulfite liquor	100.0%	

From analyses of calcium base sulfite spent liquor at the University of Washington and other data, Felicetta and McCarthy 2/ have provided estimates shown in Table I of the average proportion in which the major components in a typical spent liquor are present, based on 10% solids.

The tabulation shows that lignin, carbohydrates, and sulfur dioxide combined with lignin comprise the major constituents of the waste. These constituents are our primary concern in waste utilization, or treatment and disposal, in effecting stream improvement.

Previous studies have shown that lignin sulfonates comprise about sixty-five percent of the solids in spent liquors. Hemicellulose derivatives are also present as a mixture of hexose and pentose sugars amounting to twenty percent or so of the total solids. These sugars contain characteristic carbonyl or "reducing" groups which can be determined analytically and the "total sugar" results for the existing mixture of sugars are conveniently calculated in terms of the particular sugar, glucose. Some of the sugars such as glucose or mannose are of such chemical structure that they can readily be fermented by yeast organisms and these "fermentable sugars" may amount to about fifteen percent of the total solids. Other sugars may be present as caboxylate or sulfonate derivatives which are not "reducing" and these substances, together with small amounts of acetic and formic acids, furfural, terpenes, etc., are represented in Table I as amounting to about eight percent of the total solids. The total sulfur present in spent liquors, about seven or eight per cent of the total solids, is mostly attached to the lignin in sulfonate groups, but also exists, in small proportion, as sulfate and "free SO_2" and "combined SO_2" and other derivatives. The calcium, or another cation such as magnesium or ammonium or sodium, is present in ionic form to complement the sulfonate and other anions and the calcium present (as CaO) usually is six or seven percent of the total solids.

Sulfite waste liquor (calcium base process) is usually discharged into adjacent waterways without further treatment. However, the wood extractives in the SSL have a heat value generally given as about 8000 BTU per pound of spent liquor solids. Attention has accordingly been given to concentration and burning of the liquor. Two major problems (1) scaling of evaporators used in concerning the liquors, and (2) burning the resulting viscous liquor containing around 40% water, had to be met and economically solved if fuel values were to be recovered and pollution abated.

As regards the first problem, a unique evaporator was developed and described by Rosenblad 3/ in which the vapor and liquor heat-exchange surfaces can be switched at frequent intervals, enabling the acid condensate to dissolve scale accumulations. Commercial applications have been successfully operated at a number of Scandinavian sulfite mills and at some mills in Wisconsin and elsewhere in this country. Another solution for the scaling problem is the Ramen system, also developed and installed commercially in Sweden, where fuel costs are relatively high.

Solution of the problem of burning the concentrated SSL was provided by the Loddby burner. This equipment described by Simmons 4/ consists of a cylindrical brick-lined muffle provided with tangential air intakes extending along most of its length. The liquor atomizer at the end of the cylinder, with the muffle being outside of the furnace proper. Both drying and combustion of the concentrated SSL occurs outside the boiler furnace in such manner to provide best drying and firing conditions. The substantial investment for this equipment, despite large reductions in fuel requirements for a mill, is not considered attractive economically in areas of low fuel costs.

Installations of facilities for concentrating and burning SSL in the United States, generally speaking, have been deemed justifiable only where greater returns than from the recovery of heat values are realized, such as through sale of concentrated liquor for by-products, in addition to benefits in abatement of pollution. The economics improve when chemical values are reclaimed from the liquor along with the heat. Though recovery of the calcium base commonly employed at sulfite mills is impractical, modification of the process to use other chemical bases alters the situation. The base change to higher cost chemicals may be definitely warranted by such factors as improved pulp quality or by greater variety in the type of woods that can be utilized. The ordinary calcium base process is limited in both respects.

After extensive investigations on a pilot-plant scale by three different companies, the first commercial installation of a special recovery process for the chemicals and organic matter normally discharged as waste was made about 12 years ago at the Weyerhaeuser Timber Company Sulfite Mill at Longview, Washington. Since then other mills have been built in the United States, including two mills in Alaska.

MgO Sulfite Process: In this modified sulfite process magnesium oxide is used in place of the lime in preparing the cooking liquor. The process is generally referred to as the magnesium base sulfite process, and has been described in detail by Tomlinson, et al 5/. Because of the necessity to recover in excess of 95 per cent of the magnesium oxide for economical operation, the waste liquor is removed as completely as possible from the pulp by countercurrent vacuum washers. The washings as well as the waste liquor drained from the pulp are evaporated to about 60 percent total solids and burned in a waste liquor recovery boiler.

In addition to the recovery of the magnesium oxide, most of the sulphur and the fuel value of the organic solids, are recovered. The waste heat boiler supplies the steam required for cooking, evaporation of the liquor, and other requirements of the pulp mill in addition to supplying as a by-product much of the electric power needed in the plant.

Ammonia Base Sulfite Process: Commercial scale installations of a process employing liquified ammonia as the base in preparation of the cooking liquor containing ammonium bisulfite and sulphurous acid with an excess of free sulphur dioxide, have been made in some sulfite mills in several parts of the country. Initially, the installations were designed for burning the concentrated SSL, but considerable research has been directed toward reclaiming the ammonia base in-plant or in the form of marketable by-products.

Soda Base Sulfite Process: Another modification in the sulfite process that is probably of most interest as regards this study concerns the shift to a soda base. This change greatly extends the flexibility of the process as regards variety of woods that may be employed and quality of pulp that may be produced. While soda has the advantage of high solubility, there are some rather involved chemical reactions with the soda-sulphur compounds, necessitating application of some special procedures for chemical recovery. Some of these will be described later in this report in connection with the review of more recently developed systems which are increasingly being applied to reclaim values from the newer pulping process waste liquors and to alleviate water pollution.

The soda base sulfite pulping process, with effluent chemical recovery, probably has the greatest potential for bringing the sulfite industry into a better competitive role with the sulphate (kraft) industry. Both currently furnish low percentage yield (ratio of pulp to wood), or high grade cellulose, products. As regards fuel value recovery from the spent cooking liquors, it has been indicated that even though the fuel value per pound of solids is greater with sulfite than with sulphate, the potential heat recovery with the latter is higher per ton of product because the pulp is generally cooked to a lower yield. Such recovery items along with other pulping considerations, discussed by Dorland, et al 6/, enter into decisions as regards utilization of the soda base sulfite process rather than the conventional sulphate process.

This last mentioned process is described in detail under the following heading, as the sulphate process adapted to the cooking of the hardwoods of Missouri quite likely would be utilized in future pulp mill developments in the southeastern portion of the State. Since several of the more recent processes, such as the neutral sulfite semi-chemical process, the cold soda process and other new techniques of pulping hardwoods would be used, either as an integrated operation with the sulphate, or kraft, process, or independently, they will also be discussed - with particular attention to modern practices for reducing or using wastes,and to recovery systems that are regarded as quite important in minimizing pollution.

Sulphate (Kraft) Process

The sulphate process for making pulp evolved as an accidental modification in Danzig, Germany, about 1879 of the original soda process for separating cellulose fibers from noncellulosic substances in the wood 7/. The process gets its name from one of the principal raw materials, sodium sulphate, referred to as salt cake. The term "kraft" is also applied to this process, derived from Swedish meaning strong. A more exact name, chemically speaking, would be the "Sulphide Process", since the sodium sulphate or salt cake must be reduced before use to sodium sulphide. While sulphate and kraft have been used synonymously, kraft has come to mean the high strength product now being manufactured at many mills, particularly in the South.

Initially, use of kraft pulp was confined mostly to coarse papers and board products. Uses for the pulp have been greatly extended. At present even dissolving pulp, containing over 95% alpha cellulose, is produced by the kraft process followed by bleaching treatment for the pulp. Modifications of the kraft process have made it possible to pulp hardwoods as well as pine and other coniferous woods. These developments have contributed to a remarkable growth of the kraft pulping industry in recent years.

Continuous improvements in equipment and procedure have followed the first use of the process. Chemical requirements for kraft pulping have greatly exceeded most other processes, and its application has always depended on recovery of chemicals and heat values of the lignin and other substances cooked from the wood. Advances during the past twenty-five years have brought recovery and utilization facilities available to a high degree of efficiency.

In a modern kraft pulp mill, most of the chemicals are recovered and processed for use again. Recovery values of better than 95% can be attained. Even dust formed while processing dry materials, and previously lost, is reclaimed by electrostatic, or, more recently, Venturi scrubber, methods. Fuel requirements have been reduced by better heat recovery. New equipment keeps pulp losses at a minimum. These developments to reduce waste, together with recovery of by-products, have resulted in more and better pulp with less use of materials.

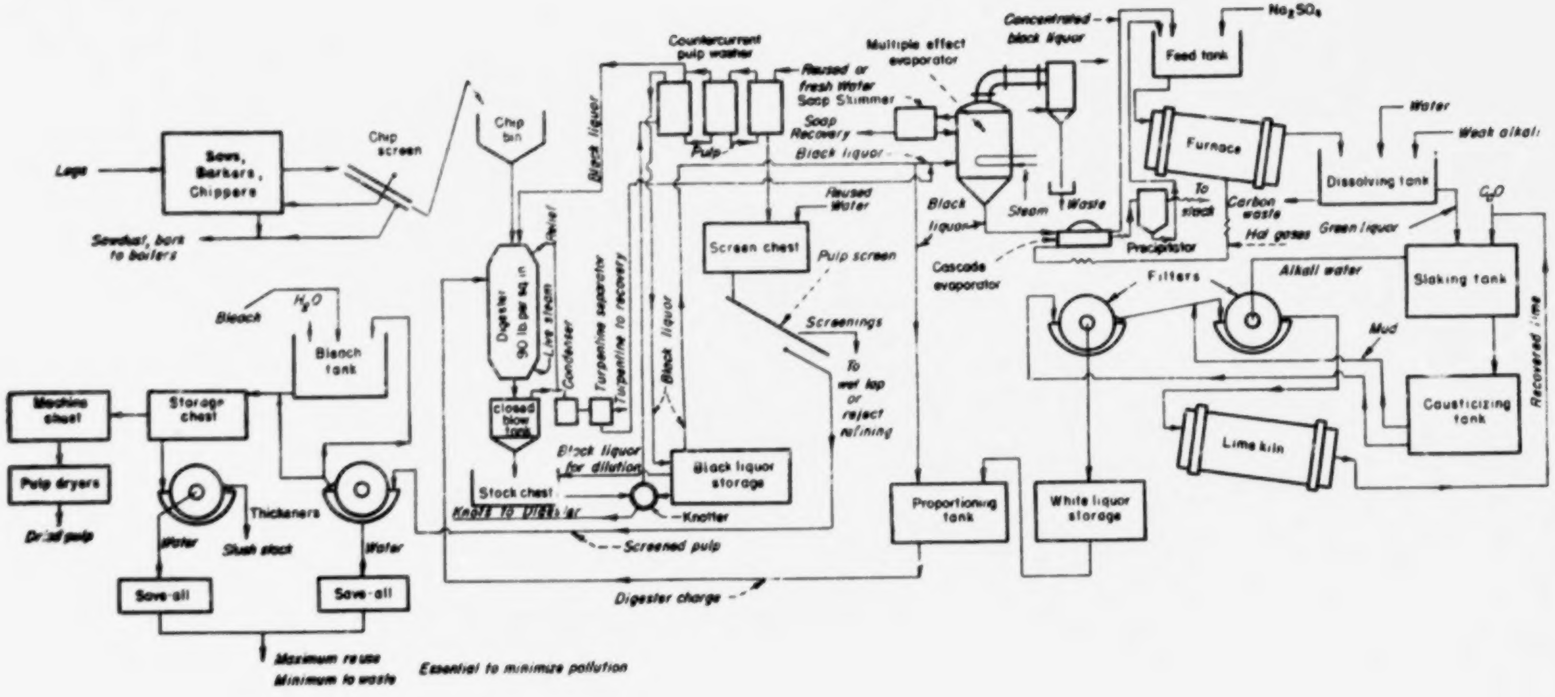
The attached flow diagram for a kraft pulp mill, Chart I, will be of assistance in connection with the following description of the kraft wood pulping process.

Wood Preparation: Pulpwood logs, sawed to suitable length, are conveyed mechanically to revolving barking drums where they are tumbled, rubbing against the sides of the drums and each other until the bark is removed. The bark falls through slots in the drums and is transported by conveyors to the boiler room where it is burned to supply a part of the mill fuel requirements. The bark has no value in paper making.

Hydraulic barking of pulpwood has been employed in some mills. The bark is removed from the logs by a jet of water operated under high pressure. The velocity of the water hitting the logs effectively strips away the bark and cleans the pulpwood. This requires large volumes of water and may occasion a disposal problem.

CHART I

FLOW DIAGRAM FOR KRAFT PULPING MILL


Logs
Saws, Barkers, Chippers
Chip screen
Sawdust, bark to boilers
Chip bin
Digester 90 lb per sq in
Relief
Live steam
Condenser
Turpentine separator
Turpentine to recovery
closed blow tank
Stock chest
Knots to digester
Black liquor for dilution
Knotter
Screened pulp
Black liquor
Black liquor storage
Countercurrent pulp washer
Pulp
Reused or fresh Water
Soap Skimmer
Soap Recovery
Black liquor
Reused Water
Screen chest
Pulp screen
Screenings
To wet lap or reject refining
Multiple effect evaporator
Concentrated black liquor
Black liquor
Steam
Waste
Cascade evaporator
Feed tank
Na_2SO_4
Furnace
To stack
Precipitator
Carbon waste
Hot gases
Water
Weak alkali
Dissolving tank
Green liquor
CaO
Slaking tank
Filters
Alkali water
Mud
Causticizing tank
Recovered lime
Lime kiln
White liquor storage
Proportioning tank
Digester charge
Bleach
H_2O
Bleach tank
Storage chest
Machine chest
Pulp dryers
Dried pulp
Thickeners
Slush stock
Water
Water
Save-all
Save-all
Maximum reuse
Minimum to waste
Essential to minimize pollution

Logs with the bark removed are either sent to storage or to chippers. These chippers are heavy rotating discs equipped with steel knives that cut the logs into square chips usually ranging from 1/2" to 1" in size. These must be screened as chips over 1" may not be thoroughly cooked in the time they are in the digesters, and chips under 1/4" would be overcooked, resulting in a loss of wood. Slivers are removed. Rejects are sent to the boiler house for fuel. The chips are stored in round hopper bottomed tanks called chip bins.

As previously indicated, there has been a trend toward preparation of wood for pulping at sites other than the location of the pulp mill. This has shown certain advantages, like more efficient and economical transportation of the chips, with partial or complete elimination of water pollution problems that might arise due to discharge of bark or other woodroom solids at the mill .

Digestion (Cooking) Process: From the chip bins, the chips are discharged into digesters, large cylindrical steel retorts in which the chips are acted on with suitable chemicals at elevated temperature to effect a separation of cellulose fibers. Though continuous digestion is now practiced, the usual batch process will be described here. A digester is charged from the top with a given amount of wood chips, and the cooking liquor is added. The cooking liquor, called "white liquor", is composed of about 2/3 sodium hydroxide and 1/3 sodium sulphide in solution. Prior to adding any liquor to the digester, the white liquor is analyzed to determine the exact amount of hydroxide and sulphide, called "active alkali". The volume in gallons necessary to give a definite weight in pounds of active chemical is then carefully measured out in proportioning tanks. This volume of white liquor is supplemented with so-called "black liquor"; the liquor once used for cooking which has practically no active ingredients left but is utilized simply for additional liquid volume in filling the digester. Following these charging operations, requiring about twenty minutes, the cover of the digester is bolted tight and steam applied to start the cooking.

The total cooking time is about 2 3/4 hours, with about 1 3/4 to 2 hours being required to raise the temperature and pressure to the correct amounts: for example, 343°F. and 110 lbs. respectively. The cooking is continued at full temperature for 3/4 to 1 hour.

During this cook, the chemical reaction is essentially hydrolysis of lignin and carbohydrates, with the formation of compounds soluble in water or excess alkali. Sodium hydroxide is the solvent that acts on the wood chips. The sodium sulphide present does not act directly on the wood, but by decomposing it breaks down to liberate sodium hydroxide as the concentration of sodium hydroxide is reduced by use. This the sodium sulphide serves as a reserve supply of sodium hydroxide, making unnecessary a high enough concentration of the sodium hydroxide at any time during the cook to decrease the yield and weaken the pulp. This reaction of sodium sulphide explains the greater yield and stronger pulp produced by the kraft process as compared with the "Soda Process", which also uses sodium hydroxide as the chief solvent. The fats and resins in the wood are saponified, rendered soluble, and later separated and recovered. This recovery is important in reducing pollution, as will be discussed later. Cellulose fiber left free and in suspension, is the pulp.

Another step in the process of interest from the waste control point of view is turpentine recovery. In the steaming of the wood chips, the digester is vented to a condenser. The condensate is passed through a turpentine separator, and the reclaimed turpentine is drawn off to storage.

At the end of the cook, the digester is "blown", the term used for quick emptying of the pulp into a container called a "blow tank". The pressure is brought down to atmospheric, reducing the temperature to about 220°F., and used for washing pulp.

Pulp Washing: The contents of the blow tank resulting from the emptying of the digester are too thick to pump. It is necessary to dilute the pulp with black liquor from storage to about 4% fiber. The black liquor used is removed from the pulp in washing operations to be described. Automatic equipment is available to control dilution.

Knots may be removed either before or after pulp washing operations, and the knots and big chips that are not cooked are returned to the digester. From the knotter the pulp, referred to at this stage as "brown stock", diluted to about 1 1/2% fiber, is sent to the washers.

In modern mills, the earlier "diffuser" washing facilities have given way to more efficient counter current pulp washers utilizing three or four rotary vacuum filters. Each of these filters has a revolving drum, or cylinder, covered with a stainless steel wire cloth with about 40 meshes to the inch. The lower portion of the filter is under a vacuum and draws the liquor through the wire cloth leaving the pulp on the wire surface, the pulp being washed by showers as the drum slowly turns.

Pulp is washed on the first filter with filtrate from the second stage vacuum filter. The pulp leaving the first stage contains 11% to 15% fiber, which is diluted to about 1% by filtrate from the second stage, passes on to the second filter unit where it is washed with filtrate from the third stage, and again thickened to around 10% to 12% fiber. The process is repeated in the third and fourth stages, except that the final wash is with hot water, reused water generally employed in keeping water requirements and losses at a minimum.

From the last rotary filter in this counter current washing system, the clean stock is discharged to storage. While it is important that the stock be clean, it is also essential that the least possible amount of water be used since it must be evaporated in the chemical recovery cycle to be described.

The washed pulp is delivered at a "consistency" of about 4% fiber to the receiving operation, passing through a weight regulator and from there diluted with water to 1 1/4% consistency going to the screen units.

Pulp Screening: The pulp may be conveyed to ordinary flat screens, or discharged through a mixing pump to a flume flowing to centrifugal screens. The latter type of screen is equipped with fine screen plates against which the pulp flow is thrown by centrifugal force. The last of the uncooked chips and knots are removed. The tailings from the screens are removed and may be reclaimed either as wet lap stock on wet machines, or may be sent to a device which mechanically breaks the rejects up into fiber in the presence of hot liquor. The fiber and liquor are discharged to the blow tank, the process being called "reject refining".

The screened pulp is passed over a thickener to take out water and produce "deckered" stock of about 8% fiber. The pulp is delivered to storage, ready now to be pumped, diluted to suitable consistency with "whitewater", or reused water, to the pulp bleaching system, or direct to the machine chest and equipment for converting the pulp into the final product.

Chemical Recovery System: As previously pointed out, the chemicals used in the kraft process are recovered in large part and not permitted to go to waste. The flow from the counter current pulp washers containing most of the spent chemicals, called black liquor because of its dark color, is conveyed to a black liquor storage tank. The black liquor goes through a chemical recovery system, which may be briefly described as follows:

Essentially the procedure involves removal of water from the black liquor by evaporation, separation of organic and inorganic materials by burning out the organic substances, addition of salt cake make up at the furnace with its chemical reduction under temperatures maintained in the furnace and causticization of the soda with lime and with later recovery of the lime by burning to remove carbon dioxide in a lime kiln. Reference to the flow diagram, Chart I, will be helpful in following the main steps in the chemical recovery cycle.

The weak black liquor is concentrated to a viscous solution of about 50% solids by steam heated, multiple effect evaporators, and subsequently evaporated further by being exposed to hot flue gases from the recovery furnace. This exposure to hot gases takes place in a cascade evaporator. In modern practice as many as six or seven evaporator units may be employed in multiple effect evaporation to make the least amount of steam remove the maximum amount of water from the black liquor.

The long tube vertical film type evaporator perfected in the United States since the 1930's has gone a long way toward overcoming foaming and carryover troubles, with attendant very low black liquor losses. During about the same period it was shown that oxidation of the black liquor by adequate contact with atmospheric oxygen ahead of the multiple effect evaporator would stabilize the sulphur compounds in a manner that substantially reduced the total sulphur losses from a mill.

A weighed amount of salt cake is added to the concentrated black liquor before being sprayed into the furnace. There is enough organic matter in the solids to burn and evaporate water left in the black liquor, with enough heat to spare for generation of steam in a boiler located over the furnace. In the furnace a reducing atmosphere is maintained to convert the sodium sulphate to sodium sulphide by the reaction $Na_2SO_4 + 2C$ + Heat = $Na_2S + 2CO_2$. This reaction requires heat in addition to that required for evaporation of the remaining water in the black liquor, but there is still sufficient over-all heat value in the liquor for production of steam needed in the process.

Development of the modern spray-type recovery furnace-boiler units have greatly increased steam production per ton of pulp over earlier equipment. Still more recent improvements, such as use of steel shot to dislodge soda-sulphur compound accumulations that tend to clog gas passages of the boiler, have accomplished much toward efficient, trouble free operation.

A molten smelt is discharged from the furnace which looks like molten slag, or iron issuing from an iron blast furnace. This smelt is essentially sodium carbonate and sodium sulphide. It is dissolved in weak wash liquor from the causticizing operations, or reused water from other sources, until a total alkali concentration in the dissolving tank of about 1 pound of sodium oxide (Na_2O) per gallon is produced. The resulting solution is known as "green liquor". When the proper concentration is reached, it is ready for use in the causticizing step in the chemical recovery cycle.

Hot flue gases after passage from the furnace through the cascade evaporator still contain considerable fine dust. In earlier days the practice was to discharge this to the atmosphere. Modern mills usually are provided with electric precipitators designed to remove more than 90% of the fine dust, or smoke particles, which are essentially very fine particles of sodium sulphate. These are given an electrical charge and in passing through an electrical grid, the particles are attracted to rods having an opposite charge. The smoke particles deposited on the rods are removed and mechanically returned to the chemical recovery system.

Some of the more recent kraft process recovery system installations have used venturi scrubbers in place of the electrostatic precipitators. In view of the use of black liquor as the normal scrubbing medium, this equipment further lowers the temperature of flue gases due to the additional water evaporated from the black liquor, thus effecting further economy by reducing need for purchased fossil fuels for mill operation. Efficiencies of removal of particulate matter by the venturi scrubbers approach those attainable by electrostatic precipitators, and even higher sulphur recovery efficiencies are indicated by recent experiences with the operation of the scrubbers when compared to results obtained with the electrostatic precipitators.

Causticizing: Green liquor is received while hot from the recovery system and clarified. Dregs removed are thickened, washed, and discarded. Clarified green liquor is discharged to storage, then heated to near boiling in connection with the next operation which is treatment with lime for causticizing. The green liquor and lime are proportioned into the slaking tank, with conversion of sodium carbonate to sodium hydroxide of about 80%, the reaction being Na_2CO_3 + CaO + H_2O = 2NaOh + $CaCO_3$. Commercial lime is used, containing some rock, so it is necessary to remove the rock and grit by a classifying unit. The material removed is washed and discarded. The causitcized green liquor requires time for completion of the above reaction, usually carried out with mechanical agitation or stirring. The time of contact under agitation is important, since the longer the time the higher the conversion of carbonate to caustic can be carried and with less excess of lime. The usual time is 1 1/2 hours. The fully causticized green liquor still containing the lime sludge is called "white liquor".

The white liquor must be freed of the lime sludge. This can be accomplished with a sludge filter, or by suitable clarifiers. The clarified liquor is discharged to white liquor storage to be used again in the pulping process previously described.

The lime sludge is then diluted with filtrate from the sludge filters, and sent to a sludge washing system. The counter current principle is again used. The clean, washed and thickened sludge, 56% to 58% solids, is conveyed to a lime kiln for calcining.

Lime Recovery: This step in the operation is essentially to convert the lime to a suitable condition for reuse. Sludge from the filters is conveyed to a gas or oil fired lime kiln, and it is subjected to increasing temperatures as it passes toward the firing end. The sludge is completely dried, and then gradually heated until the temperature exceeds 1610°F. when it is calcined to quick lime, following the reaction $CaCO_3$ + Heat = CaO + CO_2. This reaction proceeds faster as the temperature approaches 2000°F. The quick lime is then ready for further use in treating green liquor in the slaking tank.

Dust that might cause atmospheric pollution if discharged with the lime kiln flue gas can be controlled by passing through a water scrubber, trapped, and returned to the kiln.

Soda Process

Preparation of soda pulp and sulphate pulp are now commonly treated as two modifications of one process, and the procedures employed are usually referred to under the general heading of the "alkaline processes".8/. The conventional process in both cases have utilized essentially the same equipment and procedures, with only the chemical reactions being differant. The soda pulp is obtained by digesting the wood or other fibers with a caustic soda solution, which combines with the lignin and other non-fibrous constituents of the wood, leaving the undissolved cellulose to be washed free of spent cooking liquor. Chemical recovery, like with sulphate, is an integral part of the process. The soda process has ordinarily been used for reduction of short fiber woods such as poplar, birch, etc. It has largely been rendered obsolete by remarkable developments in the sulfate or kraft pulp industry, and by the technological advances in pulping hardwoods that are briefly described under the following heading.

Other Pulping Processes

In recent years, kraft pulp production has been increasingly accompanied with semi-chemical pulp production. The latter process has facilitated pulp manufacture from hardwoods. Integration of the chemical recovery systems of the two processes is also practical which is a definite advantage from the point of view of reduction of water pollution.

There are a number of cooking methods used in semi-chemical pulping of wood. In general, the term semi-chemical refers to processes in which wood chips are cooked in solutions of chemicals more dilute than commonly employed for pulping by usual processes. The treatment really softens the wood chips rather than pulping them preparatory to being defibrinated in attrition mills. Though soda, kraft, and sulfite cooking liquors can be used, the most common procedure now used is the so-called "neutral sulfite semi-chemical process, often abreviated as NSSC".

NSSC Process: This process, initially developed at the Forest Products Laboratory*, has been found to be particularly suitable for production of good quality pulps from a variety of hardwoods. 9,10,11/. The strength properties of the neutral sulfite semi-chemical hardwood pulp approach those of sulphate pulps and are appreciably higher than those of sulfite pulps made from the same woods.

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* Forest Products Laboratory, Forest Service, U.S. Department of Agriculture, maintained at Madison, Wisconsin, in cooperation with the University of Wisconsin.

The NSSC process utilizes a cooking liquor containing sodium bicarbonate and sodium sulfite. The process is shown in the accompanying flow Chart II, which illustrates three ways in which the pulp may be produced. Chips are treated in a digester for a period up to four hours at temperature up to 170°C., depending mainly on woods used and yields desired. Separation of fibers is completed with disc-type refiners. In providing pulp suitable for newsprint, for example, the process furnishes unbleached pulp yields of 70 to 85 percent from most woods. Bleaching, where necessary for higher grade products, can be accomplished by treatment with either calcium hypochlorite or sodium peroxide. When making newsprint, pulps from light colored woods, such as the poplars, do not require bleaching. Bleaching and the resulting effluents will be taken up later under a separate heading.

Chips used in the NSSC process may be impregnated with liquors before heating in the digester, the excess liquors being removed for adjustment of the chemical content before again being used for treating more chips. The portion of the chemicals remaining in the chips serves as the active digestion component in the process. Such chemicals as are left in the chips, and not removed for reuse or for discard, are for the most part washed from the pulp in processes following mechanical defibering.

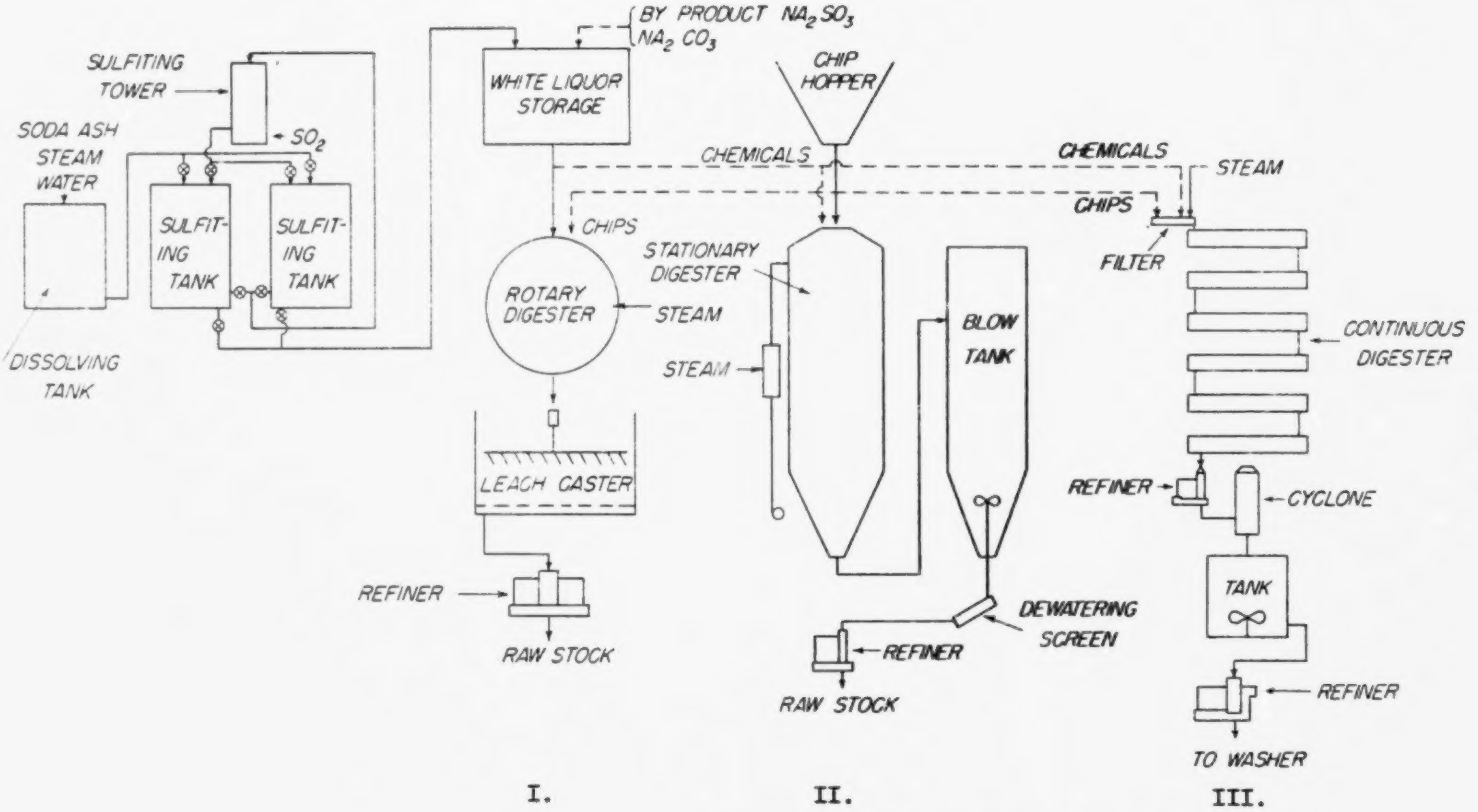
When semi-chemical operations are associated with kraft pulp mills, it is possible to dispose of the spent semi-chemical liquor as make-up in the kraft recovery system in a ratio of as much as 1 to 4 on the pulp basis. Unless the process is associated with a kraft pulp mill, recovery of the cooking chemicals has occasioned problems for the industry.

Recovery of chemicals and needs for abating water pollution have spurred considerable activity in recent years by many industry technologists and others to develop more efficient recovery systems. Semi-chemical plants not integrated with chemical pulping plants now have choice of several chemical recovery methods. At least seven such methods have been developed in recent years. Those that have been studied are the Zimmerman, Mead, Institute, Gauvin, Bradley, Sivola, and Stora-Kopparberg processes. 12,13/

CHART II

SEMICHEMICAL PULPING FLOW SHEET

I. Rotary digester system
II. Stationary digester system
III. Continuous digester system


SULFITING TOWER
SODA ASH
STEAM
WATER
SO_2
SULFITING TANK
SULFITING TANK
DISSOLVING TANK
WHITE LIQUOR STORAGE
BY PRODUCT NA_2SO_3
NA_2CO_3
CHEMICALS
CHIPS
ROTARY DIGESTER
STEAM
LEACH CASTER
REFINER
RAW STOCK
CHIP HOPPER
STATIONARY DIGESTER
STEAM
BLOW TANK
DEWATERING SCREEN
REFINER
RAW STOCK
CHEMICALS
STEAM
CHIPS
FILTER
CONTINUOUS DIGESTER
REFINER
CYCLONE
TANK
REFINER
TO WASHER
I.
II.
III.

Source: Forest Products Laboratory
Madison, Wisconsin

Referring to the simplified flow diagrams for these seven recovery systems, included in Chart III, these relatively new methods, some of which are now being commercially applied, are briefly described in the order shown on the chart.

1. Zimmerman Process: This process is a novel method of burning substances in the spent liquors, with recovery of both heat and chemical values. Basically, it depends on 'wet combustion' of most of the pollutional ingredients, or wood extractives in the liquor, under high temperature (500°F) and pressure (800 psi). Oxidation supported by compressed air under typical control conditions indicated, converts organics to carbon dioxide and water, leaving inorganic salts dissolved in the liquid. Steam and non-condensible gases generated, largely nitrogen and carbon dioxide, are removed from the liquid, and the energy reclaimed in usable form by passing the steam and gases through turbines and gas expansion engines. The liquid remaining contains the sodium and sulphur of the spent liquor as sodium sulphate, which is then converted chemically into sodium sulphite for reuse in the pulping process.

Success of burning the organics in the waste by this wet combustion method was demonstrated on a commercial scale with a 30 ton per day unit during 1954-55 by the Hammermill Paper Company at Erie, Pennsylvania, and a much larger installation has been built recently at Sharpsborg, Norway, that should provide further experience to help evaluate the effectiveness of the process.

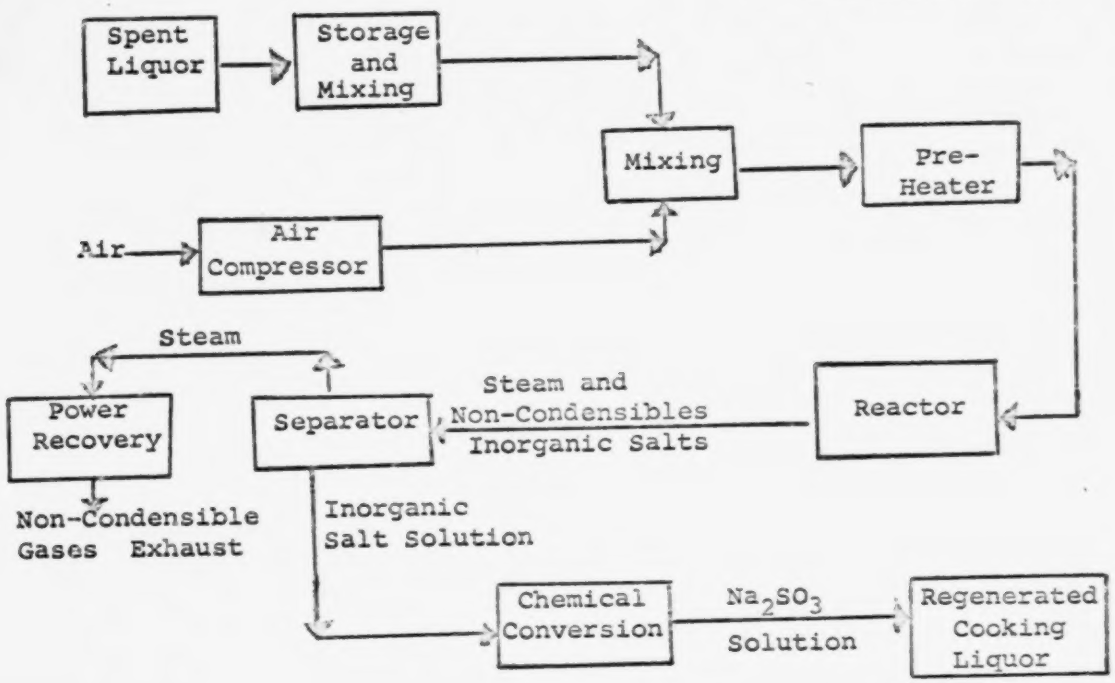
Of particular interest as regards the purpose of this study, are present applications of the Zimmerman process in sewage disposal. Pursuant to successful pilot plant demonstrations, various size installations are being made to burn organics removed from the sewage by wet combustion. These units range from the size necessary for Wausau, Wisconsin, (population 32,000) to $11 million plant to oxidize 200 tons of sludge per day at Chicago.

2. Mead Process: In this recovery process spent liquor evaporation and burning procedures are carried out similar to that described for the Kraft chemical recovery process previously; **Chart I.** Smelt from the recovery furnace containing sodium sulphide and carbonate is dissolved and clarified like outlined for kraft. Then the remaining steps in recovery are for the purpose of converting sodium sulfide to sodium sulfite for reuse in the semichemical pulping process.

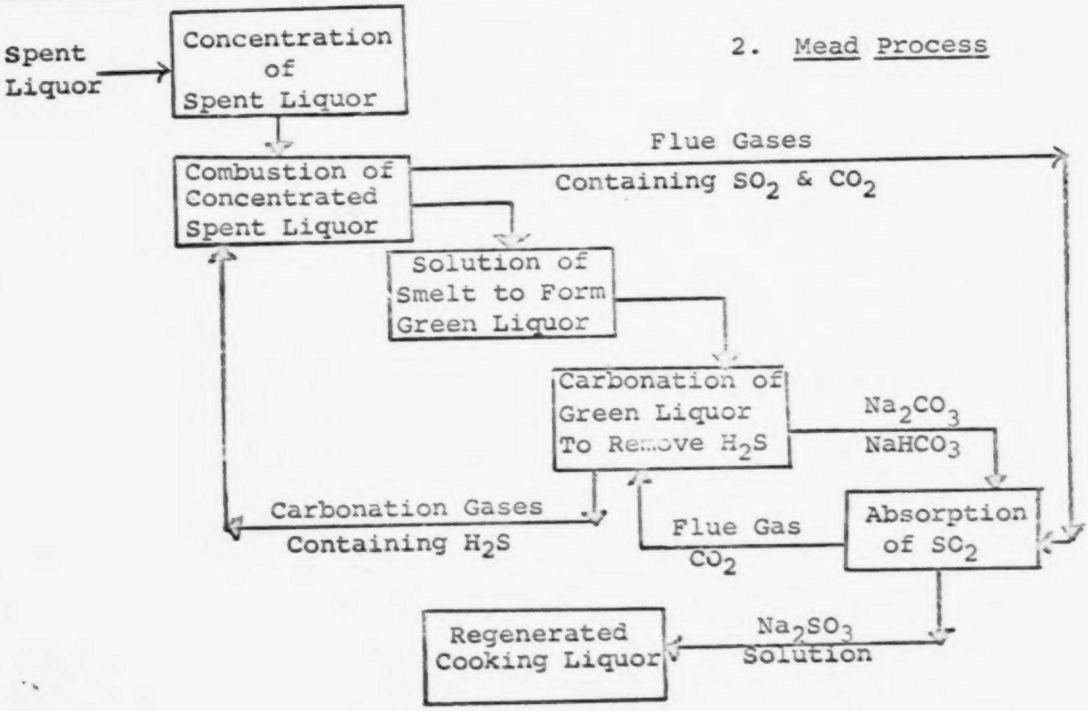
CHART III

FLOW DIAGRAMS FOR SEMI-CHEMICAL PULPING WASTE RECOVERY SYSTEMS

1. Zimmerman Process


Spent Liquor
Storage and Mixing
Mixing
Pre-Heater
Air
Air Compressor
Steam
Power Recovery
Separator
Steam and Non-Condensibles Inorganic Salts
Reactor
Non-Condensible Gases Exhaust
Inorganic Salt Solution
Chemical Conversion
Na_2SO_3 Solution
Regenerated Cooking Liquor

2. Mead Process


Spent Liquor
Concentration of Spent Liquor
Combustion of Concentrated Spent Liquor
Flue Gases Containing SO_2 & CO_2
Solution of Smelt to Form Green Liquor
Carbonation of Green Liquor To Remove H_2S
Na_2CO_3
$NaHCO_3$
Carbonation Gases Containing H_2S
Flue Gas CO_2
Absorption of SO_2
Regenerated Cooking Liquor
Na_2SO_3 Solution

Flue gas from the furnace is passed counter-current to the dissolved smelt in packed towers to permit absorption of carbon dioxide with liberation of hydrogen sulphide. The hydrogen sulphide is then returned to the furnace for oxidizing to sulphur dioxide. The carbonated solution from this step in the process, essentially free of sulphide, is further passed counter-current to the flue gas containing the sulphur dioxide in suitable towers to form the cooking liquor for reuse in pulping operations.

The initial commercial application of this process was made at Watervliet, Michigan by the Watervliet Paper Company, designed to take care of the liquor from a 50 ton per day semichemical pulp mill. This plant has been operating over two years and is now producing reclaimed pulping liquor of satisfactory quality for the pulp mill. It is reported that the value of the recovered chemical approximately covers operating costs and fixed charges. 14/

During 1959 a larger installation to take care of spent cooking liquor was placed in operation at the Mead Corporation mill at Lynchburg, Virginia, designed to process spent pulping liquor from production of 200 tons per day. 15/ The operation results obtained are quite encouraging as regards future economic application of this process in abating water pollution.

3. Institute Process: This process gets its name from the fact that it was developed by the Institute of Paper Chemistry*. The steps in the process are shown in the simplified diagram on the second page of Chart III of this report. It also uses the conventional evaporation and burning previously described. The chemistry involved is conversion of sodium sulphide in the smelt solution to sodium sulfite by direct reaction with sulphur dioxide at temperatures approaching the boiling point of water. The sulphur dioxide under conditions maintained replaces hydrogen sulphide, producing a sodium sulfite solution. Hydrogen sulphide evolved is oxidized in the furnace to sulphur dioxide and reused in the process.

Following the first commercial scale installation in 1952 by the Owens-Illinois Corporation at their Tomahawk, Wisconsin mill,

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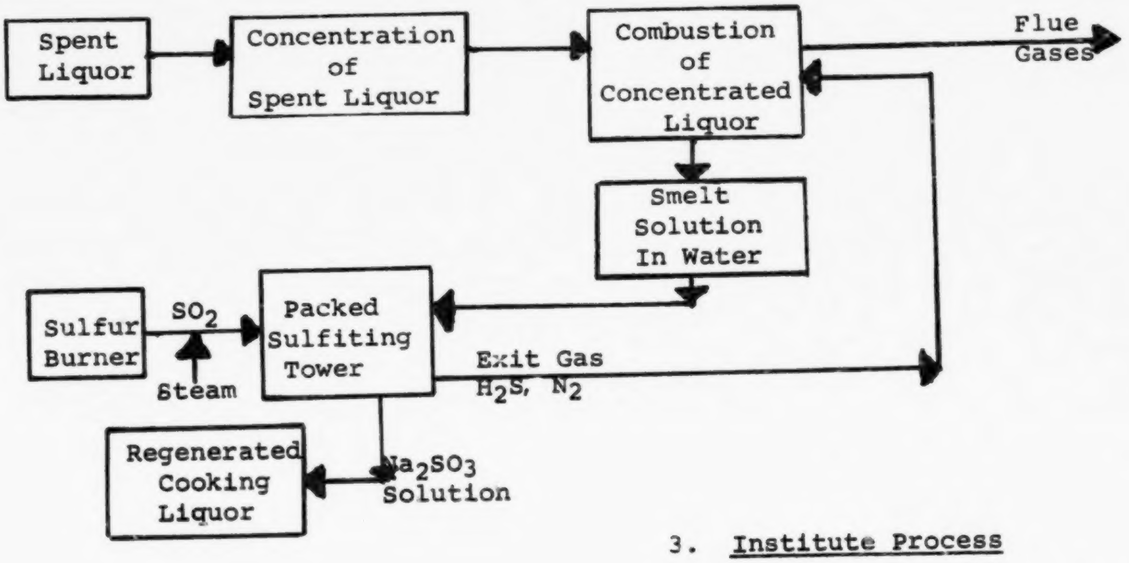
* Institute of Paper Chemistry, maintained by members in the pulp and paper industry at Lawrence College, Appleton, Wisconsin.

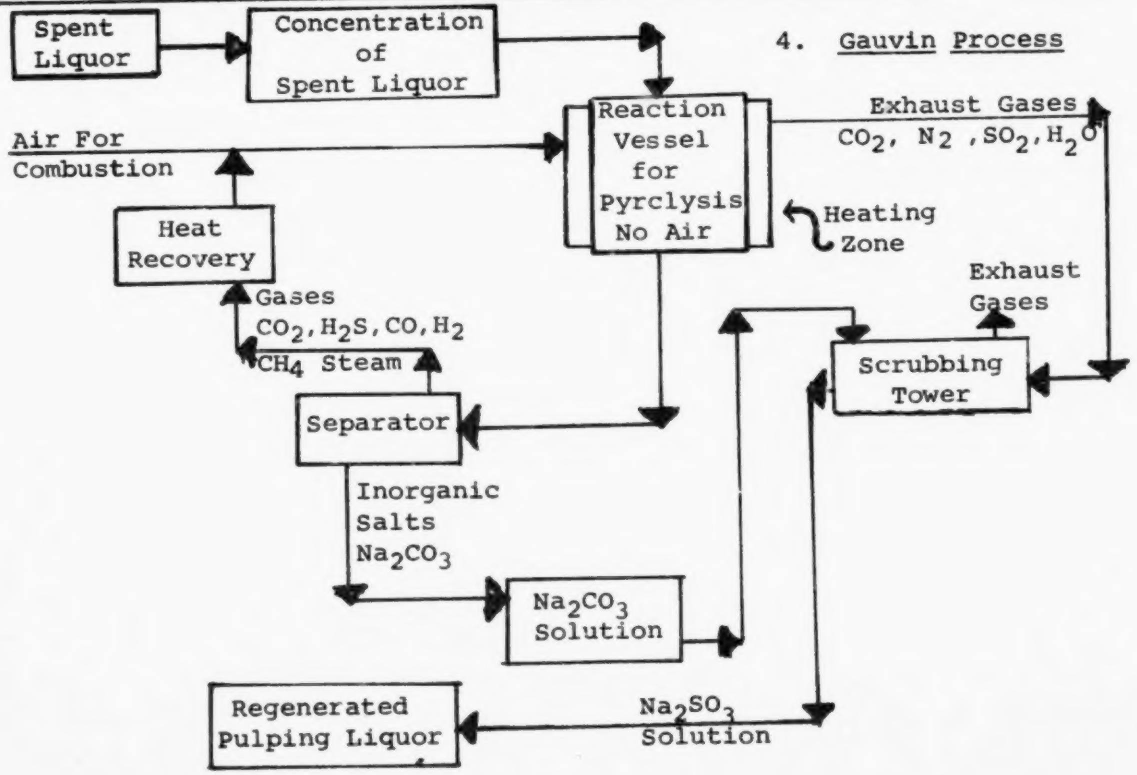
CHART III

FLOW DIAGRAMS FOR SEMI-CHEMICAL PULPING WASTE RECOVERY SYSTEMS


Spent Liquor
Concentration of Spent Liquor
Combustion of Concentrated Liquor
Flue Gases
Smelt Solution In Water
Sulfur Burner
SO_2
Steam
Packed Sulfiting Tower
Exit Gas H_2S, N_2
Regenerated Cooking Liquor
Na_2SO_3 Solution

3. Institute Process

4. Gauvin Process


Spent Liquor
Concentration of Spent Liquor
Reaction Vessel for Pyrclysis No Air
Exhaust Gases CO_2, N_2, SO_2, H_2O
Air For Combustion
Heat Recovery
Heating Zone
Exhaust Gases
Gases CO_2, H_2S, CO, H_2 CH_4 Steam
Scrubbing Tower
Separator
Inorganic Salts Na_2CO_3
Na_2CO_3 Solution
Regenerated Pulping Liquor
Na_2SO_3 Solution

succesful demonstration of the Institute process have resulted in further commercial application of the process in Virginia, North Carolina, Michigan and elsewhere. It is now a reasonably well established process both for in-plant recoveries of chemical and heat values and for reducing water pollution.

4. Gauvin Process: Another novel process is the so-called atomized suspension technique developed by W. H. Gauvin and associates at the Pulp and Paper Research Institute of Canada. This process involves high temperature pyrolysis in the absence of air. The organic portion of the spent pulping liquor is broken down to simple fractions, such as carbon, carbon monoxide, carbon dioxide, hydrogen sulphide, methane, hydrogen, water vapor and others. Sodium carbonate is the main inorganic fraction. Gases generated are separated from the solids and burned to develop the heat necessary for converting all sulphur compounds to sulphur dioxide. The sulphur dioxide is then absorbed in the sodium carbonate in solution to form the cooking liquor for reuse in the pulp mill.

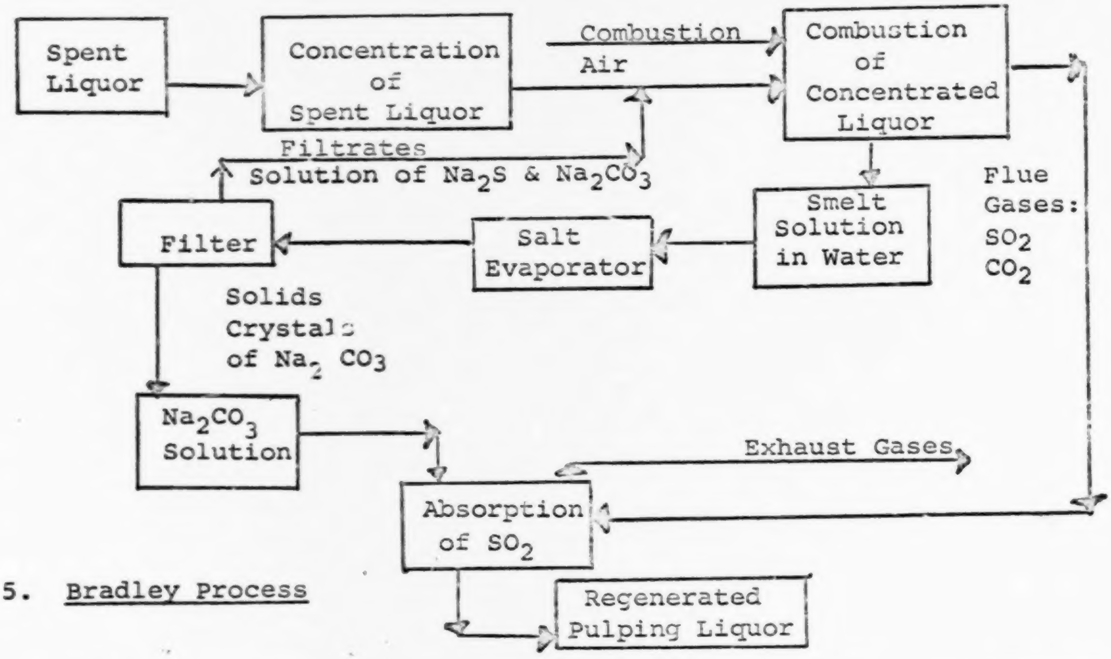
Semi-commercial scale demonstration of this process has been progressing at the Green Bay Pulp and Paper Company, Green Bay, Wisconsin. While some corrosion problems have been encountered, studies have indicated that the process has future promise in its application to semichemical recovery.

5. Bradley Process: On the third page of Chart III will be found a simplified flow diagram of the Bradley Process. An important feature of this process is air oxidation of the spent liquor prior to evaporation and burning, and of the sodium sulphide **that is** separated in a later step from the smelt solution. Such oxidation is to convert all sulphides and lignin sulphonates to thiosulphates and polythionates, which chemicals are non-corrosive. This enables construction of recovery facilities from cheaper materials. An additional advantage is the minimizing of hydrogen sulphide evolved from evaporators or recovery furnace, aiding in control of air pollution.

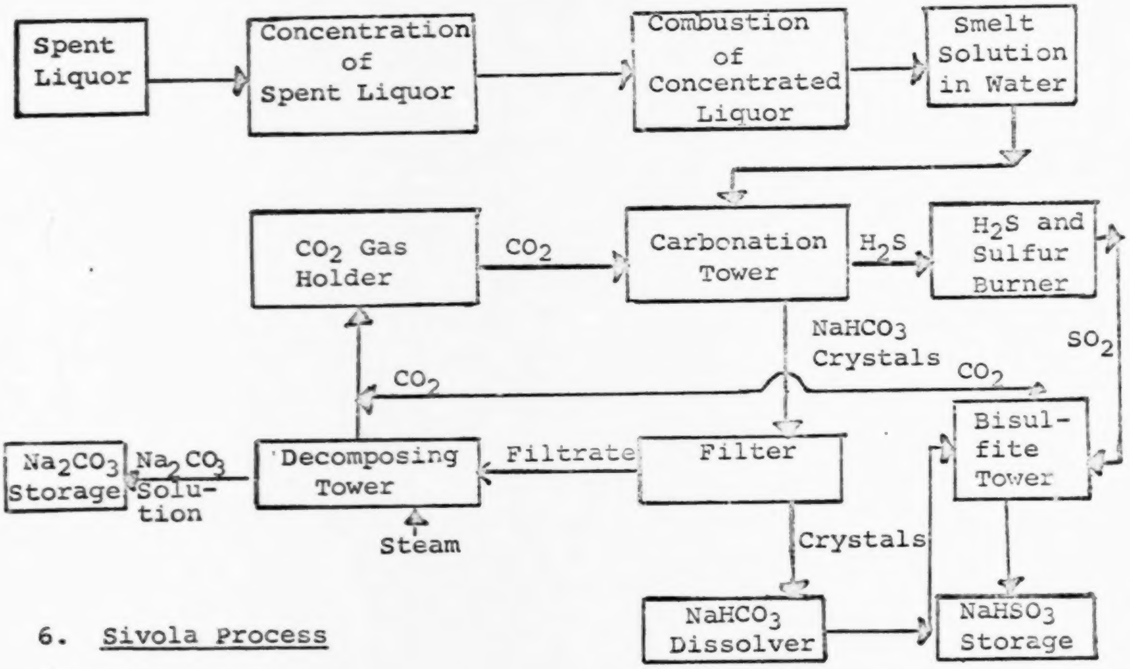
After air oxidation of the spent liquor and subsequent evaporation and burning, the smelt solution produced is concentrated in a salt evaporator to bring about crystallization of sodium carbonate. The sodium carbonate is filtered out and the filtrate containing sodium sulphide and some residual sodium carbonate is returned to the oxidizer. A portion of the sodium sulphide is decomposed to produce sulphur dioxide in the furnace flue gas,

CHART III

FLOW DIAGRAMS FOR SEMI-CHEMICAL PULPING WASTE RECOVERY SYSTEMS


Spent Liquor
Concentration of Spent Liquor
Combustion Air
Combustion of Concentrated Liquor
Filtrates
Solution of Na_2S & Na_2CO_3
Filter
Salt Evaporator
Smelt Solution in Water
Flue Gases: SO_2 CO_2
Solids Crystals of Na_2CO_3
Na_2CO_3 Solution
Exhaust Gases
Absorption of SO_2
Regenerated Pulping Liquor

5. Bradley Process


Spent Liquor
Concentration of Spent Liquor
Combustion of Concentrated Liquor
Smelt Solution in Water
CO_2 Gas Holder
CO_2
Carbonation Tower
H_2S
H_2S and Sulfur Burner
$NaHCO_3$ Crystals
SO_2
CO_2
CO_2
Bisulfite Tower
Na_2CO_3 Storage
Na_2CO_3 Solution
Decomposing Tower
Filtrate
Filter
Steam
Crystals
$NaHCO_3$ Dissolver
$NaHSO_3$ Storage

6. Sivola Process

which is fed counter current to the sodium carbonate solution prepared from the crystalline product to prepare the cooking liquor to be used in the pulping operations.

The pioneering studies of this process were conducted at the Nekoosa-Edwards Paper Company in Wisconsin, and followed by a commercial size installation at the Consolidated Water Power and Paper Company at Wisconsin Rapids, Wisconsin. The recovery system takes care of spent liquors from 75 tons per day of semichemical pulp production. Continuous operation was achieved in 1959 and valuable background has been obtained for guidance in future applications of this process.

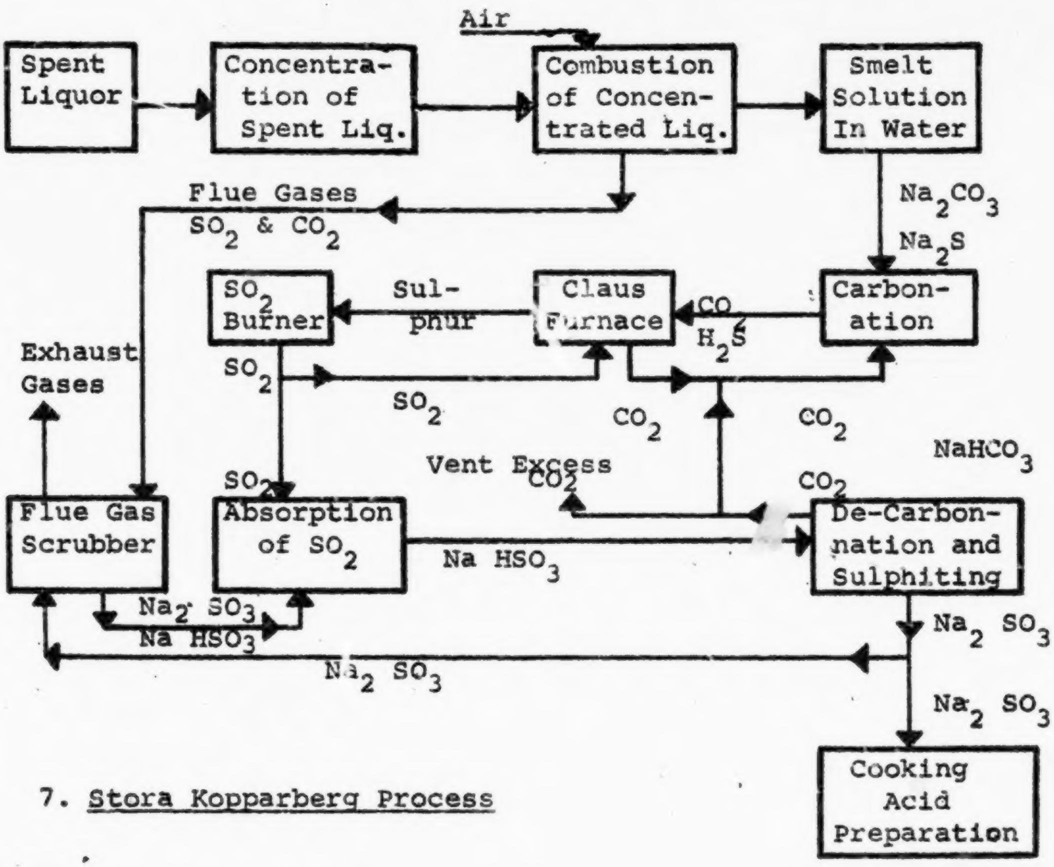
6. Sivola Process: This process is similar to, but more complicated than, the Mead recovery process. It starts with evaporation and combustion of the concentrated spent pulping liquor. In converting the smelt from the furnace into sodium sulphite for pulping operations, the 'green liquor' is carbonated to change sodium sulphide to sodium carbonate and bicarbonate. Essentially pure carbon dioxide is used in place of flue gas in the carbonation step, which is claimed to result in a better quality cooking liquor than attained with the Mead process. This claim is based on freedom of the liquor from sulphides and thio-sulphates. Hydrogen sulphide is converted to sulphur dioxide by burning. The sulphur dioxide is passed counter current to the carbonated solution to form the cooking liquor.

It is reported that this process has been utilized commercially over the past seven years in Finland, but there are no installations as yet in this country. Such information as available is based on this foreign experience. It should be noted, however, that one advantage claimed for the Sivola process is freedom from atmospheric pollution.

7. Stora Kopparberg Process: Another overseas development is the Stora Kopparberg recovery process. It differs from the foregoing porcesses in that its original purpose was to take care of the spent liquor from acid sulfite or bisulfite pulping, but with appropriate modification, it is considered applicable to semichemical recovery. The process begins with evaporation and burning of the spent liquor. The basic feature is combination of a carbonating tower with a Claus reactor to enable conversion of practically all hydrogen sulphide from the green liquor to sulphur. It is important that carbonation be carried out with pure oxygen-free carbon dioxide. Following carbonation of the

CHART III

FLOW DIAGRAMS FOR SEMI-CHEMICAL PULPING WASTE RECOVERY SYSTEMS


Air
Spent Liquor
Concentration of Spent Liq.
Combustion of Concentrated Liq.
Smelt Solution In Water
Flue Gases
SO_2 & CO_2
Na_2CO_3
Na_2S
SO_2 Burner
Sulphur
Claus Furnace
CO_2
H_2S
Carbonation
Exhaust Gases
SO_2
SO_2
CO_2
CO_2
$NaHCO_3$
Vent Excess CO_2
SO_2
CO_2
Flue Gas Scrubber
Absorption of SO_2
Na HSO_3
De-Carbonation and Sulphiting
$Na_2\ SO_3$
Na HSO_3
$Na_2\ SO_3$
$Na_2\ SO_3$
$Na_2\ SO_3$
Cooking Acid Preparation

7. Stora Kopparberg Process

dissolved smelt from the furnace, it is treated with a sodium bisulfite solution in the decarbonation and sulphiting tower. The resulting sodium sulphite solution is used in part for sulphur dioxide absorption.

Gas containing hydrogen sulphide and carbon dioxide that is exhausted in the carbonation step is reacted in a Claus furnace to produce liquid sulphur. Carbon dioxide from the Claus furnace along with carbon dioxide released in the decarbonation step, are then returned to the carbonation tower. Being essentially pure carbon dioxide, there should be a minimum of thiosulphate production.

Sulphur dioxide is scrubbed out of the furnace flue gases using some of the final sodium sulphite solution, and the Na_2SO_3 - $NaHSO_3$ mixture resulting is used to provide, through absorption of burner gas sulphur dioxide, the sodium hydrogen sulfite solution used in decarbonation and sulfiting. The burner gas sulphur dioxide is furnished through use of sulphur reclaimed in the Claus reaction along with such make-up sulphur as needed.

This process has been used at Stora's Skutskar Mill and at the Mooch Domsjo Mill in Sweden, with the first such recovery system on this side of the Atlantic being provided in connection with a new 350 ton per day sulfite mill of the Nova Scotia Pulp, Ltd.

The chemistry of the Stora-Kopparberg process, like in the Sivola process, appears to be well established through developments abroad. Though the process seems more complicated, and may have a higher installation cost than some of the foregoing processes when applied to NSSC liquors, the system finally adopted from developmental work in Sweden is reported to give a high recovery of chemicals, to have the advantages of continuous operation, to have fully automatic control, and to show only trace formation of thiosulphate, which is said to be insufficient to have any appreciable effect on the pulping process when the chemicals are reused.

There are at present some additional recovery processes in various stages of development to reclaim chemicals and other values from the spent pulping liquors. By-products of current or potential commercial use, are involved in some instances, particularly with the lower yield pulp liquors. It is impractical in this study, to go into such developments. There are many technical and economic answers yet to be obtained. Sufficient experience, however, with above described processes has occurred in recent years to indicate what might be accomplished in recovery of spent liquor from NSSC pulping of hardwoods.

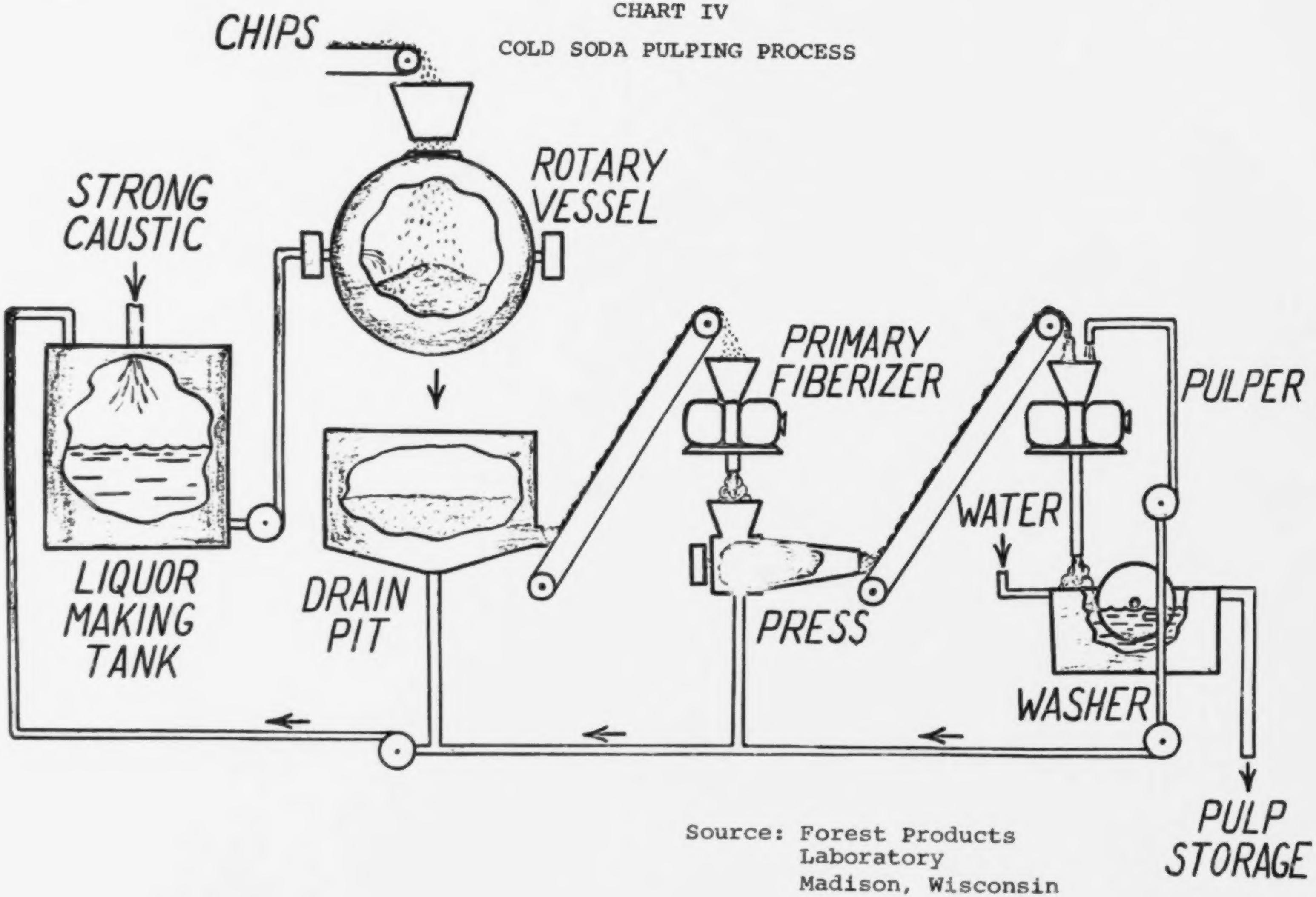
The several other pulping processes for hardwoods now being applied need to be considered here before entering into a discussion of the effects of effluents on water resources. Since only certain low density, or 'soft,' hardwoods, like aspen and cottonwood, can be used to produce suitable pulp by the mechanical, or ground wood process, the following general method has been used effectively in preparing as good or better quality pulp as compared to ordinary groundwood for which it is substituted.

Chemigroundwood Process: Developed in 1950 by Libby, O'Neil and associates 16,17/, this process (CGW) involves treating pulp wood in two or four feet lengths with a liquor containing sodium sulfite and sodium bicarbonate. Treatment is carried out in a digester with the logs first being subjected to a vacuum of 28 to 30 inches of mercury for a half hour before the liquor is added. When the chemical solution has filled the digester the temperature is raised to about 150°F, and a hydrostatic pressure of 150 pounds with a total digester pressure of 200 pounds is maintained for about six hours. Liquor drained from the digester is brought up to strength with added chemicals for reuse in further pulpwood treatment. The treated logs are then pulped with a conventional grinder, and the resulting product discharged into a system similar to that employed with the ordinary groundwood process.

It has been possible to adopt this process to both low and high density hardwoods. The yield is from 85 to 90 percent of the wood. The percentage of chemical consumed based on the oven-dry weight of raw wood for best results is about 10 percent. This loss in chemical along with the portion of the wood lost in the cooking and grinding operations, as well as such additional organics removed in subsequent bleaching operations, is of particular significance from the water pollution point of view. The amount of non-celluosic substances left in the pulp will depend largely on the paper or paperboard products for which the pulp is produced.

CHART IV

COLD SODA PULPING PROCESS


CHIPS
STRONG CAUSTIC
ROTARY VESSEL
LIQUOR MAKING TANK
DRAIN PIT
PRIMARY FIBERIZER
PRESS
WATER
PULPER
WASHER
PULP STORAGE

Source: Forest Products
Laboratory
Madison, Wisconsin

Procedures for producing useful pulps in the yield range of about 90 percent or more by refining chips softened by a mild chemical treatment have attractive possibilities for better wood utilization. Pulps of this kind made from many hardwood species, which produce groundwood pulp lacking sufficient strength for general use, have properties that make possible their substitution for softwood groundwood pulps.

Cold Soda Pulping Process: Another of the chemical-mechanical methods for producing high yield pulps now being utilized commercially with both low and high density hardwoods, is the cold soda process. 18/ Such cold soda pulps are made by steeping chips in a solution of sodium hydroxide for about two hours at atmospheric pressure, followed by fiberizing the treated chips in a disk mill, as illustrated in Chart IV. The process, as in the case of the NSSC process, was developed at the Forest Products Laboratory in Madison, Wisconsin, and was aimed particularly at making use of hardwood species. 19,20/. Employing batch methods experimented with initially in 1949, the variety of woods pulped covered most of those hardwood species found in southeastern Missouri.

The strength of the sodium hydroxide solution used in pulping is adjusted according to requirements for yield and quality. Chemical consumption accordingly ranges from 5 to 8 percent based on the weight of moisture-free wood. The mild treatment (as compared to the conventional soda process) results in removal of some hemi-cellulose, but there is very little or no loss of either lignin or alpha-cellulose.

To achieve the lowest possible chemical comsumption, the spent liquor must be recycled. Initial studies of recycling reported in 1952 21/, reviewed and reaffirmed in 1960 by the Forest Products Laboratory, in which spent liquor was collected, fortified with fresh sodium hydroxide, and repeatedly reused for pulping, gave results shown in Table II, below:

TABLE II - EFFECT OF RECYCLING SPENT LIQUOR

Number of cycles	Spent Liquor Specific Gravity	Spent Liquor Total Solids Percent
1	1.024	4.0
2	1.031	5.3
3	1.037	6.6
4	1.040	7.5
5	1.042	8.2
6	1.044	8.6
7	1.047	9.2
8	1.049	9.3
9	1.050	9.5

It will be noted from the above data that after about 10 cycles equilibrium had nearly been reached under the conditions of the studies. In other words, the material extracted in the process and accumulated in the spent liquor had practically reached equilibrium with that being carried away in the chips. It was concluded that the spent liquor from the cold soda process might be reused indefinitely.

Though chemical treatments from one to two hours are now customary when steeping chips at atmospheric pressure, the time required may be reduced to thirty minutes or less by applying hydrostatic pressure to the liquor in contact with the chips in the digester, or treating vessel. It was further shown that by applying the cold soda solution at the same time chips were being defibered in a refining type mill, that good quality pulp could be produced on a continuous, rather than batch, basis 22/. Advantages realized by continuous operation are better uniformity and quality control. No drain off and reuse of liquor is involved, as the spent chemical and such organic matter as dissolved from the chips is carried along with the defibered material to be removed in subsequent washing and bleaching, or succeeding steps in converting the pulp into printing papers, corrugating board, and other products. 23,24/.

Various conbinations of pulping techniques have been studied and applied commercially, but the procedures previously described are considered of most interest as regards future expansion of the pulp and paper industry into Missouri. Since pollution characteristics of effluents from pulping and recovery processes likely to be employed are basic in this study, they will be discussed under the following heading prior to consideration of further steps and effluents in the manufacture of paper and paperboard products.

PULPING EFFLUENTS

The introduction of pulp mill wastes into a stream will have some effect on the character or quality of the water in it. Unless adequately controlled, their impact on a stream may include removal of dissolved oxygen, fiber bottom deposits, toxicities to fish and fish foods, color, tastes and odors, foaming, and stimulation of Sphaerotilus growths. The important consideration is whether such changes as may occur will adversely affect existing and future desirable uses of the stream below the pulp mill and the extent or degree of any detrimental effects on such water uses.

Substances in solution or suspended in pulp mill waste waters, partly inorganic but mostly organic in nature, may have quite adverse effects either near to the mill or some distance downstream if they are discharged into a watercourse providing inadequate dilution. It is essential to keep polluting substances in waste waters well within the amounts that can be inoffensively assimilated by streams under low flows and warm weather conditions, if satisfactory stream conditions are to be maintained.

The most common characteristic of pulp mill effluents of importance from the water pollution point of view is their oxygen demand, or ability to extract dissolved oxygen biochemically from the waters receiving them. It should be explained here that the waste loading , or degree of pollution, is usually measured by the 5-day biochemical oxygen demand (B.O.D.). This determination measures the amount of oxygen that will be consumed by the waste waters or mill effluent Values are now usually reported in terms of pounds of oxygen required per ton of product.

Sulfite: Oxygen demands of pulp mill effluents vary greatly - from a few pounds per ton for groundwood pulp to five hundred pounds and upwards per ton for sulfite pulp, where the SSL contains practically all of the non-cellulosic material in the wood along with the spent chemicals. In the case of the groundwood no chemicals are used and most of the non-cellulose components remain in the pulp. In sulphite pulping, however, amounts of chemicals used will usually be 8 to 10 percent of the dry weight of the chips, or for the ordinary calcium base process, the weight of chemical per ton of pulp (dry weight) will be about 450 pounds. The SSL will contain most of this, only altered by reactions in the digester, along with over fifty percent of the weight of the wood pulped.

The 5-day B.O.D. of the spent sulfite liquor varies considerably, depending on the type of "cook", woods used, and other conditions. Analytical results of sulfite mills in the Pacific Northwest have indicated that the 5-day B.O.D. values have exceeded 600 pounds per ton of pulp. Such results are somewhat greater than the average. Tyler 25/ reports the following approximate contributions of components of SSL to the over-all 5-day B.O.D. of the liquor:

Component	Per cent of Actual B.O.D.
SO_2 (Immediate Chemical Demand	11
Sugars	63
Acetic Acid	12
Alcohol	1
Lignin furfural, etc.	13

Aside from the sulfur dioxide (SO_2), responsible for the immediate demand on the dissolved oxygen resources of the stream receiving the SSL, the principle ingredients of concern from the water pollution point of view are the sugars.

When discharged into a stream, these sugars increase the supply of food for bacteria, yeasts and molds - including such growths as Sphaerotilus natans. Under some conditions this last mentioned growth has caused particularly objectionable conditions. For instance, this slimy growth has been reported by fishermen to seriously interfer with operation of gill nets along the Columbia River below sulfite pulp mills, necessitating special control measures.

The sugars in the SSL promote rapid development of extremely large numbers of organisms that require oxygen, tending to deplete dissolved oxygen in the receiving waters in proximity to, or downstream from, a sulfite mill. The requirements of organisms for oxygen may be sufficient to reduce the normal dissolved oxygen of a stream to such extent that not only the organisms but also fish and other animal forms may perish.

The fact that sugars in SSL are readily attacked by microorganisms caused early investigation of fermentation processes for production of salable by-products for economic utilization of the sugars. Only two of the many processes described in the literature have had any appreciable commercial application to date in this country. These are processes for alcohol and edible yeast production. The first utilizes only the fermentable sugars (hexoses) while the latter uses in addition the nonfermentable sugars (pentoses). Two commercial installations for production of yeast proteins in Wisconsin have been successfully operating in recent years. 26/. About 90% of the sugars are removed from the strong liquor, with the B.O.D. reduction ranging from 50 to 65%. Residual substances not converted in the yeast growth account for the remaining B.O.D. The fact that hardwood SSL pentose sugars content is substantially greater than with softwoods makes yeast production of more significance with the trend toward more pulping of hardwoods.

The other principal organic constituents of SSL, lignin and lignosulfonic acid, are relatively inert as regards effect on the dissolved oxygen of receiving waters, but color, acidity, and other characteristics are factors to be considered. Burning of the lignin and other organics, with or without chemical recovery, can reduce the B.O.D. of the SSL up to about the same degree as obtained with recovery system for kraft, but corrosion and scaling characteristics of the liquor, coupled with the relatively cheap fuel situation in this country, have retarded commercial application of combustion methods. Utilization of lignosulphonates for by-products offers more attractive means for future use of such pollutional ingredients of SSL, with research producing an increasing number of valuable marketable products.

Small amounts of fiber, or suspended material, may be lost with the sulfite pulping effluent, but for economic reasons the loss of fiber is kept at a minimum.

Under existing conditions it is thought that major consideration in this study should be directed toward effluents from the alkaline pulping operations, particularly the sulphate, or kraft, and semi-chemical processes, where considerable progress has been made and experience obtained in solving effluent problems associated with pulping of hardwoods.

Kraft: The waste effluents from the kraft pulping process previously described carry materials the amounts of which depend upon equipment provided to reduce losses and efficiency of individual plant operation. About half of the pulpwood used is dissolved in the cooking liquor leaving a residue of cellulose fibers as pulp. Spent liquors contain the lignin, hemicellulose and sugars from the wood along with chemicals and a small amount of fiber lost in the washing and dewatering operations. Most of the dissolved materials are concentrated and burned for their fuel value in the chemical recovery system.

In modern kraft mills the procedure in handling wastes consists essentially of burning the bark from the pulpwood, burning or recooking the knots, reprocessing or marketing the rejects and screenings, recovering and selling of turpentine and tall oil, reclaiming of lime sludge from the caustisizing operation, recovering the fiber for including in the product, along with the reclaiming of the heat values of dissolved substances in the spent cooking liquor and chemicals utilized in the process.

Chemical recovery has reached a high state of efficiency. Operating results at modern mills have shown 95% recovery. Modern mills are fully equipped to keep both stack and sewer losses at a minimum. Pesch 27/ has reported that improved equipment and practices have resulted in 'drastic reductions' in B.O.D. figures for unbleached kraft pulp mill effluents, per ton of product, particularly during the past fifteen years. Results as low as about 30 pounds of B.O.D. per ton of unbleached product are indicated. In the sulfate wood pulping process, or the kraft process, a recovery system for the cooking liquor is an integral part of the mill. Further reference to Chart I will be of assistance in the following discussion.

The process depends economically on efficient reclaiming of the spent cooking liquor and reuse of its chemicals. Chemical recovery is not complete. An appreciable amount of alkali and extracted substances from the wood escapes in the so-called black liquor lost in the process. The losses in the liquid wastes are principally in the final pulp washings. The condensate from the evaporators, the digester degassing condensates, and the blowdown condensate from the digester have all been found to contain polluting material.

The major waste from the pulping operation is overflow from the decker seal pit. This effluent contains traces of chemicals and wood substances remaining in the pulp after the washing operation. The greatest improvement in this part of the process has come through the elimination of wash water effluent. Development of closed countercurrent vacuum washing systems has been responsible for this advance which has led to both higher recovery efficiency as well as a reduction of the B.O.D. load in the effluent of between 50 and 75 per cent. Decker seal pit discharge varies between 200 and 500 ppm. of 5-day oxygen demand. Other pulp mill discharges are digester relief and blowdown condensates, together with log wash water, turpentine decanter water and floor washings. These are low in volume as compared to the decker seal pit overflow and generally have a lower oxygen demand. They are significant, however, in that the condensates, decanter water and floor washings contain substances such as sulfides, resin acids and mercaptans that are potentially toxic to aquatic life. When danger of reaching toxic levels in the receiving waters exists, the condensates are stripped of objectionable substances in packed towers by power plant stack gases.

In the heat and chemical recovery system of the kraft process the major effluent is the condensate from the evaporators. Where surface evaporators are employed the volume of this discharge is low and the B.O.D. value relatively high. Barometric condensers produce an effluent very low in oxygen demand, but voluminous, due to the quantity of water required by the jets. Application of long tube evaporators in as many as seven effects has greatly reduced carry-over with the resulting high losses formerly occurring in this operation. Improved foam control and trapping devices have further reduced carry-over of liquor into the condensers. A better appreciation of evaporator capacity requirements in relation to losses has also done much to reduce the concentration of organic matter and salts in this discharge. Other waste waters emanating from this part of the process are minor in both volume and pollutional load. Processing differences, plant equipment and production all affect the volume of effluent discharged, but a fair average range would be between twenty and forty thousand gallons per ton.

Pesch 28/ presented a chart in his discussion of improvements in the kraft recovery process indicating the unit production relationship of water usage to pollution load. The B.O.D. in pounds per ton of unbleached pulp increased from about 30 pounds to nearly 60 pounds as water used in pulping operations increased from 20,000 to 40,000 gallons per ton.

Kraft pulp mill wastes may add some color, odors and possibly cause some foaming in the stream below the mill waste outlets. Under certain conditions some wood fiber may be deposited on the bottom of quiescent areas of the stream, some of which may later rise to the surface. The high fiber recovery efficiency attainable in modern mills, however, tends to minimize this possibility.

Certain sulphur compounds, such as mercaptans, are produced in sulphate pulping operations and may get into mill waste waters unless carefully controlled. Mercaptans, which are sulphur ethers or alcohols, have very disagreeable odors and are toxic to fish life if the concentrations in a stream exceed about one part per million. Amounts of mercaptans formed, however, are small, and usually can be kept well below the critical levels for fish and aquatic life.

Bergstrom towers have been used for treatment of condensates, or potentially toxic effluents, to remove the mercaptans and sulphides, and to keep loss of resin acids at an unobjectionable minimum. 29/. Much effort has been directed toward eliminating toxic components. Van Horn and associates 30/ have carefully studied various constituents that might cause difficulty to help in devising and applying adequate control measures.

The sludge from causticizing operations in preparing fresh cooking liquor from the recovered chemicals is another possible source of pollution. Most modern mills take care of the sludge by 'burning' the carbonate sludge to reclaim the lime for further use in the process, or they lagoon the sludge for use as agricultural lime. A few mills convert it into whiting. This sludge, therefore, should no longer be a pollution problem.

Wastes that remain for disposal include lime slaker grits and dregs from the causticizing step in preparation of the cooking liquor. These insoluble inorganic materials are usually disposed of in lagoons, or are dewatered and disposed of as fill near the mill.

As previously indicated, the process waste water or effluent that needs to be disposed of from a kraft mill will usually range between 20,000 and 40,000 gallons per ton. A combination kraft pulp and paper mill, including bleaching of pulp, might result in about 60,000 gallons of effluent. 31/. This is made up of those waters not reused in the process, and which contain varying amounts of spent chemicals and wood substances not reclaimed in the steps previously described. Such an effluent is either discharged directly from the mill, or is lagooned for controlled release, or is given suitable treatment prior to entering a stream or other waters.

Semichemical: As quite likely in pulping of hardwoods, semichemical production may be integrated with a kraft pulp and paper mill. It is practical under such circumstances to dispose of the spent semi-chemical liquor as make-up in the kraft recovery system in a ratio of as much as 1 to 4 on the pulp basis. Unless the process is associated with a kraft pulp mill, recovery of the cooking chemicals must be accomplished by recovery processes or treatment, or both. Recovery processes such as previously described reduce the B.O.D. from 50 to 90 percent.

No such combined recovery system is reported as practical in the use of the acid sulfite process, utilizing calcium, magnesium or ammonia base cooking liquors; and the soda base process has never become widely established in this country. Therefore, Kraft+semi-chemical processes, singly or in combination, will probably be utilized with hardwoods of Missouri.

Replacement of acid sulfite with semi-chemical pulping will reduce pollution on the B.O.D. basis about 75 percent. Investigations conducted by the National Council for Stream Improvement at Virginia Polytechnic Institute have indicated that about 75 percent of the oxygen demand of neutral sulfite semi-chemical waste is due to sodium salts of the lower fatty acids, mainly acetic. From 5 to 10 percent of the 5-day B.O.D. of the waste is immediate demand due mainly to residual sulfites and associated compounds. Other cellulose degredation products, and wood residues, account for the remaining 20 to 25 percent.

Components of the spent liquors from semi-chemical processes are similar to, but less in amount than those found in liquors from the usual sulfite, kraft, and soda processes. Oxygen demands are four to six times that of a kraft pulp mill per ton of product. The lignin, though less than in SSL, is sufficient to add color to waters receiving the wastes, the degree varying with pH from pale straw color to black at high pH values. Tannates present add to the color, particularly if iron is present in the surface waters. Organics tend to stimulate aquatic slime growths. Accordingly, some method of waste reclamation or reduction is important.

The color is caused by lignins and tannins which have little if any oxygen demand. Since the waste is substantially neutral and does not appear to contain any strongly toxic materials, color and oxygen demand are the major problems as regards stream pollution.

With no chemical recovery or treatment, low yield neutral sulfite semichemical pulping effluents contain approximately 275 pounds of 5-day B.O.D. per ton of pulp, with the range being from 125 to 350 pounds per ton depending on woods pulped in the usual yield range (65-85%). If the B.O.D. reductions indicated above, by existing recovery methods, are inadequate for pollution control, waste treatment and disposal methods will need to be provided.

The cold soda semichemical process, particularly well suited to hardwood pulping at high yields (88 to 92% or more), due to the recycling employed in the batch process reaches equilibrium with liquor containing about 9 to 10% solids in solution. Cold soda, as well as kraft, semichemical spent liquors can be combined with either conventional kraft or soda process spent liquors and reclaimed in the usual recovery systems.

Chemimechanical methods of pulping do not really involve 'cooking' with chemicals to solubilize non-cellulose constituents of the wood. 32/. Chemical liquors used are only to suitably soften the pulp woods prior to defibering in attrition mills. Most of the wood components remain in the product. The wastes, accordingly, are comparatively of much less importance as regards oxygen demand and other pollutional characteristics. Minimizing fiber loss is important, as in the case of all of the previously described processes.

Groundwood: Since the ground wood pulping process employs only a mechanical grinding of wood, the effluent from this process carries in solution only a very small amount of water-soluble material extracted from the wood. Also carried in suspension is a small amount of fine wood fibers which pass through the wire screens used in dewatering the pulp.

The effluent from groundwood pulping will generally range from 3 to 8 pounds of 5-day B.O.D. per ton, with 10 pounds per ton as a reasonable figure for the waste waters from a well-designed and operated unbleached groundwood pulp and paper operation. The volumes of effluent will usually range from 4,000 to 16,000 gallons. While aspen and cottonwood can be used for a number of paper and paperboard products without bleaching, higher grade pulps sometimes involve such steps as hydrosulfite bleaching, which will add to the waste load. The bleaching of pulp is discussed briefly under the following heading.

PULP BLEACHING

Pulp bleaching is an essential step, irrespective of the pulping process used, in the manufacture of high-grade pulp and paper products. No matter how rigorous the pulping process, whether produced by the acid sulfite or alkaline processes, there is always associated with the cellulose a portion of the liquor or incrusting matter ordinarily present in the raw fiber. Such colored impurities are not removed by washing or mechanical treatment. A chemical bleaching process is necessary.

The purpose in bleaching practice in the paper industry is to thoroughly treat the pulp with suitable bleaching agents to turn out a product of maximum whiteness and purity, which will remain white indefinitely and yet not impair the strength and natural properties of the fiber, not cause too much shrinkage in weight and volume, and not have excessive consumption of the bleaching materials.

Bleaching is primarily an oxidizing reaction. Chlorine is the most common bleaching agent, and in its various forms is extensively used by the Industry. Initially, single-stage bleaching was employed, with the washing away of the soluble waste products from the insoluble bleached pulp. This practice has gradually been superseded by multi-stage bleaching where strengths of the chlorine and chlorine compounds are just sufficient to take out part of the solubles in each stage, thereby securing maximum pulp yields of good quality, with minimum chemical usage.

The washings between each chemical treatment stage in the bleaching process, containing such solubles as removed in this oxidation process, constitute the principle effluent. The volume and strength of such effluents will vary widely depending in considerable measure on the quality of the pulp used and grade of paper products to be produced.

Herbet and Berger 33/ recently described results of laboratory and pilot-plant tests of a kraft bleach waste color reduction method integrated with the recovery process. The method provides for the entire lime load being slaked in and reacted with the full caustic extract stream. Following sedimentation, the lime-organic sludge is dewatered by vacuum filtration or centrifugation and used for causticizing the green liquor. Results indicate more than 90% reductions in color, 45% decrease in B.O.D. and a resulting cooking liquor suitable for production of bleached kraft pulp.

No attempt will be made to go into any detailed account of converting the pulp into paper products. To provide some understanding of the procedures employed and waste ingredients, the following brief outline of paper manufacture is presented:

PAPER PRODUCTION EFFLUENTS

In the paper-making process, the sheet is formed by filtering the fibers from a water suspension on a fine-mesh wire screen of the Fourdrinier, or, paper machine. In the formation of the paper sheet, the water passing through the screen (white water) carries a considerable quantity of fiber. In order to avoid large losses of fiber, this white water is recirculated through the system. In other words, instead of adding fresh water for washing and dilution of pulp stock, the white water is added for this purpose. However, it usually results that there is a surplus of white water over that needed for make-up and the unused portion, after passing through filters or settling tanks, is discharged into the mill effluent. In addition to the cellulose fibers, white water effluent from the paper mills may contain some clay or other mineral fillers, alum, rosin-size, and dye used in the manufacture of various kinds of paper. The quantities of suspended solids in the effluent from both pulp and paper mills may vary considerably among individual mills.

This is a result of the different products being manufactured, the process used, type of equipment available, and method of operation.

The so-called 'white water' wastes, applied to the fiber and other paper-making materials in suspension, are kept at a minimum by recirculation. Save-all equipment is employed to remove the paper-making solids in the white water before discharge from mills. There is usually some type of filtering or clarifying device designed to return the reclaimed material to the pulp and paper making process. Utilizing more recent equipment, the losses of fiber may be reduced below a half pound per thousand gallons of effluent.

PAPERBOARD EFFLUENTS

In general the principles employed in reduction of white water wastes in paper mills are being followed in decreasing fiber losses in the manufacture of paperboard. The trend is toward recirculation of as much of the white water as possible without causing processing difficulties. This closing or partial closing of board mill white-water systems has increased the problem of slime control. As in paper mills, the situation has been met by use of antislime materials in the water, such as chlorine, chloramine, pentachlorophenate, and other compounds for suppressing biological growths. It is important to maintain careful control of such antislime compounds, or special processing wastes, that may contain enough free phenol to impart tastes to downstream water supplies.

Filtration, settling, and precipitation systems have been utilized to remove suspended solids from board mill wastes. For such solids as cannot be effectively and economically returned for use in the mill, disposal in lagoons may be the answer from the point of view of stream improvement.

WASTE TREATMENT

Process and equipment improvements have resulted in a definite trend downwards in the volume and strength of pulp and paper mill effluents. The strength of the wastes on an oxygen demand basis has been decreased as much as 75 percent by such improvements, with attendant reductions in chemical requirements, and other gains. Monitoring equipment is proving of value in avoiding occasional increases in sewer losses. The work on waste reduction is nearing an irreducible minimum, however, and further reductions necessitate consideration of treatment and disposal methods.

The Forest Service, U.S. Department of Agriculture, reported 34/ approximate B.O.D. values for various pulping processes, expressed in terms of pounds of oxygen per ton of pulp produced, as shown in the following tabulation:

Process	B.O.D.
Groundwood pulping	3- 8
Sulfate pulping	55- 70
Cold-soda pulping*	50-100
Deinking plant wastes*	**60-100
Semichemical neutral sulfite pulping*	125-350
Sulfite pulping*	500-600

Even though some pulp mill effluents today are considerably weaker in pollutional characteristics than they were a few years ago, effluent disposal may involve more than dilution to avoid impairing the quality of the receiving waters. Such measures for treatment and disposal as have been employed in recent years with kraft mill wastes, have been directed toward reduction of waste components toxic to fish life as well as reduction in oxygen demand 35,36/. In-plant improvements have removed a large portion of toxic sulphides and mercaptans from the composite mixture of blow steam condensate, evaporator condensate, and digester relief condensate following separation of the turpentine which is usually marketed or burned.

Usually when the effluents are controlled to maintain adequate dissolved oxygen in the receiving stream, problems of toxicity to fish will be satisfactorily overcome. Also with adequate stream dilutions at pulp mill sites there should be no appreciable effect on the quality of the waters for irrigation purposes 37/.

Treatment procedures are usually necessitated by insufficient dilution being available in the receiving waters. The need and type of treatment is related to stream use. It may be seasonal or continuous. Ponding or lagooning of wastes may be employed, or other more recently developed methods for the solution of special problems, can be applied.

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* Without recovery or treatment

**Per ton of waste paper processed

Lagooning has been utilized with beneficial results in reducing the strength of kraft mill wastes, and in equalizing the flow and variations to be expected in strength of mill wastes. The use of lagoons of suitable capacity for effluents, therefore, gives flexibility in handling of wastes to avoid objectionable conditions during periods of low stream flow and highest water temperatures 38,39/. Special studies in recent years to increase the efficiency of lagoons have been conducted by the Industry through their National Council for Stream Improvement, and much information is available on performance of this method for treatment and disposal of kraft mill effluents.

Biological methods of treatment practiced by some kraft pulp and paper mills include oxidation ponds, other natural purification procedures, and the accelerated aeration process. A natural purification method of increasing popularity in the southern United States consists of passing the mill effluent down a natural or man-made waterway before discharge into the receiving stream. The accelerated aeration method which consists of effluent oxidation in an aeration tank by means of biological sludge or floc was experimentally developed by the National Council for Stream Improvement. A mill at Covington, Virginia, treats all of its wastes from wood preparation through bleaching operations by the accelerated aeration process and accomplishes high reduction of the oxygen demand of the mill effluent 40,41,42/.

Progress is being made in the removal of color from kraft mill wastes 43/. Color may be removed by treatment of the effluents with high dosages of hydrated lime. This treatment produces large volumes of hydrous sludges which are difficult to de-water. In view of the amount of lime required for good results, it is necessary for economic reasons to recover the calcium content of the sludges for re-use. Promising methods of the sludge treatment, employing carbonation and heat, are being developed 44/.

Small daily losses of fiber from a pulp and paper mill may result in an extensive accumulation of fiber with time on the bottom of a receiving stream. It is especially true with a slow moving river or a fairly quiescent area such as a reservoir. Such a mat of fiber tends to smother the aquatic organisms on which fish feed and will undergo slow decomposition which contributes to the benthal or stream bottom oxygen demand. Modern "save-all" equipment, such as vacuum filters, and water recycling systems, properly installed and operated should adequately take care of the fiber problem.

SUMMARY ON WASTES

The usual procedure in pulp and paper mills is to reduce wastes at their source, reclaiming as much of processing chemicals and wastes as practical, returning these materials to the system for pulp and paper manufacture. An increasing number of by-products have been developed from wastes. Reduction in mill losses have brought about very substantial decreases in pollution caused by effluents.

Recycling of process waters has done much to reduce volumes of effluents. As indicated, the usual volumes per ton of kraft pulp in modern mill practice range from 20,000 to 40,000 gallons. The volumes of effluent increase to around 60,000 gallons per ton for a modern kraft pulp and paper mill employing 'standard' in-plant waste control measures. This makes no allowance for hydraulic debarking of the pulpwood, as other practices, inclusive of securing peeled and chipped wood delivered to the mill, may be employed. Integrated kraft and semichemical recovery processes are expected with use of hardwoods. The strengths of the wastes should definitely be kept under an over-all 5-day 20°C B.O.D. loading of 70 pounds per ton. With careful operation the strengths should be substantially less than this figure.

A low yield neutral sulfite semichemical mill would produce an effluent having about 275 pounds of 5-day B.O.D. per ton of pulp should there be no chemical recovery. With anticipated use of one of the available recovery systems the indicated B.O.D. loading can be reduced 50 to 90 percent. The most thoroughly demonstrated method of NSSC chemical recovery on a commercial basis is that of combining NSSC and kraft spent liquor for reclaiming of chemicals through the kraft recovery system. As regards groundwood pulp and paper production, the B.O.D. loadings will not usually exceed 10 pounds per ton of product.

The B.O.D. is considered to be the most important, or controlling parameter in considering mill wastes in relation to water resources. Other items such as settleable solids, color, odors, taste production, toxicity for aquatic life, etc., must also be given careful attention, particularly where dilution is limited and there is likelihood of impairment of water for other uses.

The modern trend is toward monitoring of effluents, using automatic control equipment to reveal increases in strengths of wastes due to leaks, spills and other unusual or emergency conditions arising in mill operation. Diversion of wastes at these times to lagoons, or other suitable means have been utilized to avoid "slugs" of pollution. It is very important to make provision for avoiding such difficulties in the design and construction of new mills.

Local situations will also involve consideration of waste treatment, in addition to use of most efficient recovery systems and in-plant practices. Sedimentation methods, with or without sludge processing, and biological oxidation types of treatment, from ordinary oxidation ponds to the relatively complicated modified activated sludge waste treatment system now utilized by some mills, may be provided to meet regulatory requirements and maintain a high degree of cleanliness in the receiving waters.

Summarizing briefly integrated kraft and semichemical pulp and paper mill waste disposal procedures, consideration should be given to the following items:

1. Dry bark and waste wood - should be utilized or burned, ashes to be kept out of streams.
2. Screen rejects - reclaimed or burned.
3. Grit and dregs from lime slaker - disposed of on dump, or utilized for fill, surfacing material, etc.
4. Tall oil and soap - to be removed and either marketed or incinerated. Quite important with softwood pulping.
5. Fly ash - to be disposed of other than discharged to stream.
6. Fibers in white water - to be kept at minimum by efficient saveall system.
7. Chemicals dissolved in effluent - loss to be kept at minimum with modern reclaiming equipment, including countercurrent vacuum filter washing of pulp. Consider waste monitoring and control equipment and lagooning for wastes.
8. Lime sludge - recovery and reuse, or disposal for agricultural lime.

9. Sanitary sewage - treated and disposed of in a sanitary manner.

10. Refuse - incinerated or disposed of in such manner as to be kept out of streams.

The possible procedures in final disposal of the used waters from a mill require attention. It is practical sometimes to use land disposal for effluents containing a substantial part of the waste load. Disposal by soil seepage or evapotranspiration in woodlands has been successfully practiced. This will be limited to areas where no ground water supplies will be affected. Dispersion of effluents, with employment of diffusers in streams, needs study to facilitate securing maximum dilution with available flows. Intermittent discharges may be beneficial in suppressing undesirable aquatic growths. These and other disposal techniques and control measures can be studied and applied where suitable when specific plans are being proposed for mill installations.

Such considerations have entered into the estimates of effects of mill wastes on streams at sites previously indicated. Other factors involved are discussed in the following sections.

MAJOR FACTORS IN THE STUDY

Basic in this study is multiple use of water resources. Application of principles and practices of good water quality management will be necessary if maximum benefits are to be derived through contemplated industrial and other developments without jeopardizing present or future uses of the streams for public and other authorized purposes.

Regarding the importance of water in future development of industry, the statements of John G. Strange* in opening a Pulp, Paper and Paperboard Industrial Waste Conference in Chicago, December 1-2, 1959 are significant:

"...Taking all aspects into account, therefore, it can be said that the paper industry is more critically dependent on water, and especially high quality water, than the balance of industry. It is apparent that this dependency will have a more restrictive influence on future expansion than any other single economic or raw material factor.

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* President, the Institute of Paper Chemistry, Appleton, Wisconsin.

"...As industry emerges as the principal user of water, it automatically assumes several important responsibilities, two of which have particular meaning to this conference. These are the prudent and effective handling of the water which it takes in, and reasonable treatment of the water which it releases..

"...Industry's responsibility for the condition and quality of its discharged water involves, it seems to me, three major considerations. These are, the protection of public health; the maintenance of wildlife and recreational facilities; and, the suitability and cost of released water to subsequent users."

It was pointed out with regard to water pollution control considerations, that underlying these problems is the doctrine of multiple use eloquently stated by Justice Oliver Wendell Holmes when he said "A river is more than an amenity. It is a way of life that must be rationed among those who have power over it."

In making streams increasingly useful, serving the surrounding economy as well as the many other important public interests, the primary purpose of stream management requirements is to assure that those who enjoy such services do not create conditions that will unduly impair the quantity or quality of the water for use by others.

Regulatory Requirements:

The State agency having the primary responsibility for water pollution control in the State of Missouri is the Missouri Water Pollution Board. The Board was established by an Act of the 1957 Legislation. The Act defines "pollution" as the discharge of sewage, industrial or other wastes into the waters of the State in such condition, or quantity as to cause the waters to be contaminated, unclean, impure, odorous or noxious to such an extent as to be detrimental to public health, to create a public nuisance, to kill or have an unreasonably harmful effect upon fish or other aquatic life, or upon game or other wildlife, or be unreasonably detrimental to agricultural, industrial, recreational or other reasonable uses. The Act also defines "Waters of the State" as all rivers, streams, lakes and other bodies of surface or subsurface water lying within or forming a part of the boundaries of the State which are not entirely confined and retained completely upon the property of a single individual, partnership or corporation. (Secs. 204.010-204.170; (Laws of Missouri, 1957, Senate Bill No. 25))*

In establishing powers and duties of the Missouri Water Pollution Board, the Act authorizes the Board to develop a comprehensive plan for the prevention and reduction of pollution after a study of existing practices and available research. It is also empowered to establish and revise standards of water purity which specify the maximum degree of pollution permissible in accordance with public interest in water supply, the conservation of fish, game and aquatic life, and agricultural, industrial and recreational uses. Before establishing or revising the standards of water purity, the Board must consider the technical means available for the reduction of pollution, the economic factors involved, and must hold an open public hearing with reasonable notice to persons whom the Board knows are interested therein. The Board must give opportunity to any persons who wish to be heard upon the question of standards of water pollution at the time of the public hearing (Sec. 204.080 (4)(9)).*

The Act also provides for issuance of permits and review of plans and specifications. Should anyone desire to erect or modify facilities or an operation of any type which will result in the discharge of sewage, industrial or other wastes into the waters of the State, they must apply to the Board for a permit. The Board may require the submission of plans and specifications and other information. In issuing a permit, the Board may specify therein conditions under which the discharge is to be made. A permit is also required before anyone may: (1) construct, or modify any outlet or system for disposal of sewage, industrial or other wastes when such disposal constitutes pollution as defined in the Act; (2) increase the volume or strength of any sewage or other wastes in excess of permissive discharges specified under any existing permit. The Board is authorized to modify or revoke permits; however, it must give the permit holder 30 days' written notice of its intention to do so (Sec.204.030)*

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* Citations refer to Vernon's Annotated Missouri Statutes and Cumulative Supplement thereto.

The Board is authorized to adopt rules and regulations for the administration of the Act and for conducting meetings and hearings (Sec. 204.080(6)(8))*. It may hold hearings, and issue orders and permits (Sec. 204-050(4), 204.080(7)).* Its agents may enter private or public property at reasonable times to investigate conditions relating to pollution and to inspect the operating records of any sewage system, or waste treatment plant (Sec. 204.130)*.

As regards enforcement, anyone who violates any provisions of the Act or order of the Board promulgated pursuant to the Act, is punishable by a fine of not less than $25 nor more than $500, or by imprisonment for not more than 90 days in the county jail, or both. In the event of a continuing violation, the person becomes liable to a fine of not more than $100 for each day the violation continues after a final decision has been rendered finding that a violation has occurred (Sec. 204.170)*.

The State of Missouri Conservation Commission administers laws, which among many provisions relating to fish and wildlife, include a provision relating to pollution which directly relates to this study.

The conservation statutes make it unlawful for anyone to place any deleterious substances into any waters of the State in quantities sufficient to injure, stupefy or kill fish. It is not a violation for anyone engaged in industry, to cause or permit any water subject to his control or used in such industry to be so discharged under such precautionary measures as have been specifically approved by the Conservation Commission (Sec. 252.210).*

The Conservation Commission, in considering possible location of pulp and paper mills in Missouri, recently announced the following policy: "The Conservation Commission recognizes the possible establishment of pulp mills in Missouri as a potential and beneficial use of forest resources, but would be forced to object to the establishment of such mills in locations where stream pollution might result in serious damage to fishery resources.

"The Commission feels that it must call attention to the pollution problems that exist in pulp operations, in varying degree, depending upon the process of pulp manufacture. Such pollution can have harmful and longrange effects upon fish, and also upon recreational pursuits in the affected areas.

"Therefore, the Conservation Commission feels that the location of any pulp mill, and type of process it utilizes should be carefully considered, and that the Water Pollution Board of this State should insist that rigid standards for the maintenance of water quality be established by any such operation before an operating permit is issued." *

The reference on mill developments by the Conservation Commission quoted above highlights the fact that the present Water Pollution Law, Chapter 204, Revised Statutes of Missouri, Cumulative Supplement, 1957, requires consideration of all legitimate water uses. The Water Pollution Board under the law requires that the following interests be represented: the public at large; recreation and wildlife; industry; municipal; mining and agriculture. Since October 1, 1959, under a directive of the Governor, all matters pertaining to water pollution in Missouri have been placed directly under administrative control of the Missouri Water Pollution Board.**

Water Quality Objectives:

During the conference in Jefferson City, Missouri, just preceding the reconnaissance survey, and during further conferences, held at the University of Missouri, November 14-15, 1960, consideration was given to water quality criteria to be used in connection with this study of potential pulp and paper mill sites in southeastern Missouri. It was indicated that water quality objectives have been developed and were adopted January 7, 1954, by the Engineering Section of the Missouri Basin Health Council, for use as a guide for the pollution control program along the Missouri River. Other such objectives are being utilized along the Mississippi River. These guides, copies appended, (Appendix I), have been employed by the State of Missouri in the development of its part of comprehensive pollution control activities for these particular rivers, and have been used as fundamental information in preparing this report.

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* Missouri Conservationist, Vol.21, No.6, P.5, (June, 1960).

** Johnson, Freeman R., "The Missouri Water Pollution Control Program", Proc. 6th Annual Air and Water Pollution Conference, The University of Missouri Bulletin, Vol. 62, No. 25, (Eng. Exp. Sta., Series 53), p. 3, (November 15, 1960).

It was brought out during the above mentioned conferences and subsequent correspondence that the water quality objectives should be considered as minimal in this study. They apply specifically to the main stems of the two rivers, with the tributaries, and other streams in the State, to be treated individually. No objectives, or cleanliness provisions, for the Gasconade, Current, Black, St. Francis, Big or Meramec Rivers have been established by the Missouri Water Pollution Board.

The decision reached was to make the five parts per million dissolved oxygen provision of the currently established objectives (Appendix I) serve as the low limit for the purposes of this study. Oxygen resources at each site visited have been accordingly computed with this minimum dissolved oxygen figure as a basic limiting factor.

Generally the most important effect of pulp and paper mill effluents on aquatic life is considered to be the removal of oxygen from the water into which the effluent is discharged. If the volume of water receiving the effluent is not large enough, or its oxygen content is low, the oxygen utilized may result in reduction of the dissolved oxygen to a level below that necessary to sustain fish life. Such mill wastes may also have toxic effects on the fish and fish food organisms in a stream if dilution is inadequate. This may be the limiting factor in streams having relatively high dissolved oxygen resources.

As regards dissolved oxygen, toxic substances, temperature, pH, turbidities, and other conditions important in the aquatic environment in sustaining fish and fishery resources, this report would not be complete without reference to the monumental work (1937) of Professor M. M. Ellis of the University of Missouri while in charge of Interior Fisheries Investigations of the then Bureau of Fisheries, U.S. Department of Commerce 45/. This comprehensive treatise, from country-wide studies, correlated the physical and chemical characteristics of streams with existing bottom fauna, plankton and fish. These findings have helped greatly in subsequent work of biologists in establishing requirements for the aquatic habitat. It was shown that good fish faunas were not limited to localities where the waters are fully air saturated, but Ellis' data does tend to support the minimum dissolved oxygen objective of five parts per million, for maintaining an active fish population. 46/.

The effect of kraft and semichemical pulp mill wastes on existing and possible future installations of drinking water supplies is the introduction of color, taste and odors. The probable extent of such effects needs to be considered. Color is particularly intense in kraft and semichemical wastes. It is difficult to reduce color by any simple means and the most feasible solution is adequate dilution after such in-mill and treatment reductions as practical so that the color does not exceed 20 (platinum-cobalt scale) at any downstream water supplies.

Some of the more potent taste and odor producing substances in mill wastes would be unstable under aerobic stream conditions and would disappear rapidly. If the wastes receive adequate treatment and dilution, and if downstream water supplies are sufficiently distant, it is expected that taste and odors would be below threshold levels at the point of water intake. At the treatment and dilution contemplated for the wastes, there should also be no problem when using the receiving stream for irrigation.

Water quality objectives attached (Appendix I) include restrictions based on esthetic considerations, which are particularly important in stream areas utilized for bathing, boating, fishing, and other recreational activities.

Reference has already been made to stimulation of aquatic growths by ingredients of some pulp mill wastes. Sufficient stripping out of nutrients by recovery or treatment methods, or by other control measures, to avoid excessive development of sphaerotilus natans and other such growths, need to be given attention to avoid aquatic nuisances.

Other guiding considerations concerning mill effluents in relation to water quality objectives are set forth in Appendix I.

Survey Data:

This study did not include a detailed field survey of the streams for the collection of specific analytical data indicating the present sanitary, biological, physical, and chemical condition of the waters. Data utilized in this study were limited to those which were available from existing records of various governmental and private agencies, except the few field water analyses made during the reconnaissance survey and reported in Appendix II. These were intended primarily to get some idea of dissolved oxygen under low flow - warm weather conditions that prevailed at the time of the survey.

Such analytical work as performed during the field work involved in this study indicated most waters were at or near saturation for dissolved oxygen at the prevailing temperatures; with stream conditions observed being generally favorable as regards existing water quality.

It was evident from the study that there is very limited basic water quality data for the streams in Missouri. There is need for a comprehensive program to supply this necessary water quality information.

Stream flow data were obtained from records furnished by the Missouri Water Pollution Board and from Surface Water Supply publications of the Geological Survey, U.S. Department of the Interior. Stream temperatures were also obtained in part from Geological Survey records, or were ascertained from records of the Weather Bureau, U.S. Department of Commerce, using the technique described by Velz, 47/. Information on the relative importance of fishery resources and extent of other uses of the streams was obtained both from publications and inquiry of persons familiar with them. In connection with this part of the study, very helpful information was furnished by Mr. John L. Funk and included as Appendix III of this report.

Data on the types and quantity of wastes presently being discharged to the streams were obtained from the Inventory of Municipal and Industrial Waste Facilities in the area involved. This inventory was cooperatively developed by the States and the Public Health Service.

It was necessary to estimate the present dissolved oxygen concentration and biochemical oxygen demand of the stream waters from knowledge of the characteristics of the streams, pollution known to be entering, and related information obtained from the Missouri Water Pollution Board and through the Public Health Service, Regional Office VI, Kansas City, Missouri.

Data concerning mill wastes used in the study, as has been indicated, appears in publications of the Forest Products Laboratory, Forest Service, U.S. Department of Agriculture, derived in considerable part from extensive analyses of such wastes by the Wisconsin State Board of Health and State Committee on Water Pollution; in releases and abstracts provided by the Institute of Paper Chemistry; in technical articles and releases of the National Council for Stream Improvement of the Pulp, Paper and Paperboard Industry; in journals of the Technical Associations of the Pulp and Paper Industry (TAPPI); and in various public documents and technical literature cited in the references accompanying this report. In addition, much helpful background has been gained through conferences and correspondence with both industry and public officials, and with individuals conducting special studies on utilization, treatment and disposal of pulp, paper and paperboard effluents.

Information and data on forest surveys and practices have been provided from State and Federal studies, results of which in both published and unpublished form were made available by Mr. John Wylie and Mr. Lewis Harrison as background for this work. Additional helpful background was obtained from University of Missouri publications, such as the bulletins of the Agricultural Experiment Station and Engineering Experiment Station; from the Missouri Conservation Commission publications, such as the 'Missouri Conservationist', 'Rivers of Missouri', and articles on sport and commercial fishing; from releases of the Resources and Development Commission of Missouri, such as the 'Tourist Survey for 1959'; and various other State and Federal documents. Sources of such background are indicated as far as practical by legend, text, footnotes and references. The survey participants have contributed much. Only such aids as extended by all concerned made this undertaking possible.

It should again be stressed, despite the large amount of information secured, there is definite need for basic water quality data for the rivers of Missouri. Lack of actual analytical results for streams and supporting facts made it necessary to resort to engineering judgement in many instances. It is

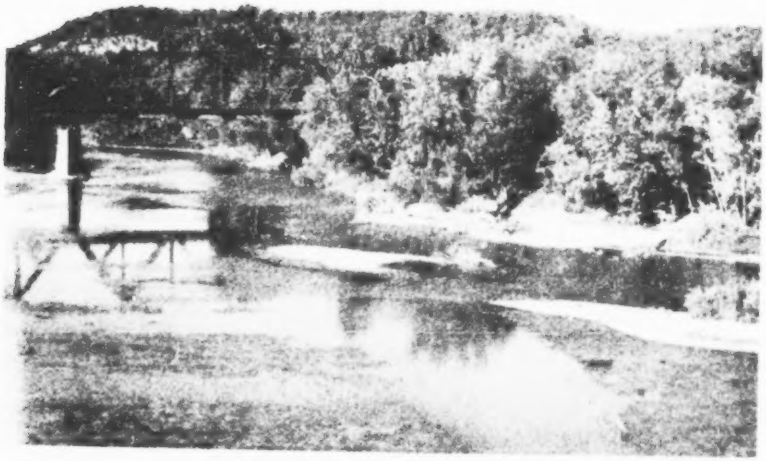

Figure 8. Gasconade River near Jerome, Missouri - Only stream tributary to Missouri River studied in relation to possible establishment of pulp and paper mills in Southeastern Missouri

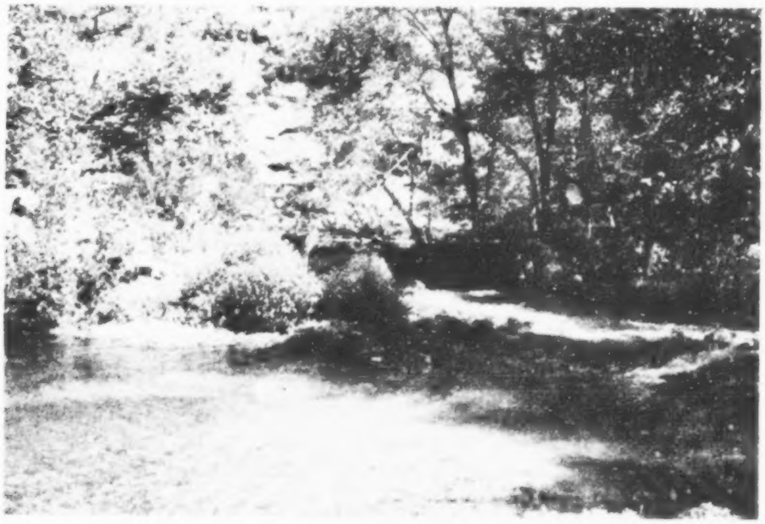

Figure 9. Flow from Alley Spring, tributary to Jacks Forks and Current Rivers near Eminence, Missouri.

hoped that this important need can be met in the future by a comprehensive program for determination of water quality.

Characteristics of Basins - Ozarks

All streams included in this study, with the exception of the portion of the Mississippi River involved, have certain characteristics in common. They originate in the highlands of the Ozarks, drop steadily downward from their sources along watercourses that are moderately to fairly steep in the upper reaches, and emerge finally in the hilly to partially flat lands of the Missouri-Mississippi River Border Region. Their headwaters are situated in heavily forested areas, which tend to retard rapid runoff of rainfall and help keep down sediment loads in the streams.

The rivers are well aerated by numerous riffles or rapids along the watercourses in the Ozarks, and the surface waters are augmented throughout much of the region by moderate to quite large flows of clear, cool water from springs: See Figures 8 and 9. Some of these springs are listed among the largest in the United States 48/. The flow from Alley Spring, shown in Figure 9, is one of twelve in the general area that are listed as having average flows of 100 cfs or more. The temperature of these spring waters is reported to seldom vary more than one degree from the average figure of 58 degrees Fahrenheit, which was the temperature observed, recorded in Appendix II, when sampling some of the spring waters tributary to streams included in this reconnaissance survey.

These springs have particular importance as regards the quantity and natural quality of waters in the rivers during dry periods. They serve as outlets for what may be regarded as large underground storage reservoirs underlying the Ozarks Plateau. The underground formations tend to distribute the portion of the mean annual rainfall of about 43 inches that seeps into the aquifers which is discharged to the rivers over more or less prolonged periods. Discharges from springs usually reflect increased infiltration during wet weather. A study by Bretz 49/ of caves and springs of the area includes discussion of the nature of openings associated with flow of ground water in the underground formations. He states "The Missouri big springs, the dominant visible feature of subterranean drainage in the Ozarks, are all discharged from below the water table...

Figure 10. Flow averaging 390 cfs (252 MGD) from Big Spring to Current River at State Park four miles southeast of Van Buren, Missouri.

Figure 11. Current River at Highway 160 Bridge near Doniphan, Missouri.

They are the result of 'lateral flow in the upper zones of the water-table' but this flow is below the lowest drought levels of the table". It is evident from the information available that the large amount of storage in the underground drainage systems feeding these springs exerts a strong effect in increasing dry-season flows in the rivers.

In general, the number of springs having approximate average flows of 10 cfs or greater decrease in the basins of the Gasconade, Meramec, Big, Current, Black and St. Francis rivers as they flow from the headwaters in the Ozark Plateau North and northeast to the Missouri-Mississippi River Border Region or South to the Missouri-Arkansas State boundary. Only the Meramec has a few such springs located in the river border region. The St. Francis River Valley has only a small number of springs listed as having large flows as compared to the Black and Current River Basins to the West. The influence of the spring discharges on low flows was strikingly brought out during the severe drought of 1936 50/ by comparative studies of river flows in the St. Francis and Current River Basins; some results of which are shown in Table IV, appended. 51/. During this drought the precipitation in Missouri for the months of May through August, 1936, was 6.30 inches or only 37 percent of the mean for this period for preceding years of record (1889-1936). The precipitation in the St. Francis River Valley was somewhat below this mean while that in the Current River Valley was somewhat higher. However, the mean flow in the St. Francis River at Patterson was .012 cfs per square mile of upstream drainage area as compared with .467 cfs for the Current River at Doniphan for the low flow month of August, 1936; with approximately 62 percent of the flow at the latter place being ascribed to large springs, such as Big Spring, Figure 10.

In addition to stabilizing effects on river flows during dry weather periods, the discharges from the springs in the Ozarks influence to a large degree the chemical characteristics of the river waters below their outlets at low river stages. Water analyses to establish the chemical nature of the waters flowing from the springs, mainly during dry seasons, have been made in the past. Data are considered to be fairly representative of what might be shown by the same analyses at the present. Typical analyses for some of the largest springs in the indicated river basins are shown in Table V, Appendix V. 52/.

Review of analyses of sample of the 90 springs included in the report cited show that, in general, the springs are not highly mineralized and that the waters are only moderately hard. It is indicated that the waters are not as hard as found with deep well waters in the Ozark Region. These waters would conform favorably with TAPPI water quality provisions for mill water supplies. 53/.

Analyses of the waters of some of the big springs sampled during the reconnaissance survey were for the main purpose of determining dissolved oxygen content and thereby obtaining some data for estimating the extent to which the flows from the springs would contribute to oxygen resources during low flow-warm weather conditions. Determinations made by Mr. Herbert J. Fisher, given in Table III appended, all approached saturation at the prevailing temperatures and elevations. Results along with other information obtained were most helpful in estimating oxygen resources of the streams in various sectors included in the survey.

It was apparent that these waters afford habitats suitable to fish and aquatic life. Fish were observed in pools near outlets from these springs and at various places along the rivers in the Ozarks, giving visual evidence of facts brought out along the way concerning the nature and quality of fish and sport fishing in the region. Since facts available from State Conservation Commission Studies have been assembled and have been very adequately set forth in Appendix III and discussed in relation to this survey, they will not be repeated here. It will suffice to say that fish and sport fishing furnish one of the major recreational assets of the region.

In fact, the streams and impoundments in the Ozarks, along with the forest clad watersheds with many scenic attractions, are noted for the many recreational opportunities they offer. In addition to sport fishing, with the famous 'float trips', hunting, bathing, boating and camping opportunities have attracted numerous vacationers and visitors to these areas, and provide a significant source of income for the region.*

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* Expenditures for tourist and pleasure-travel in Missouri were reported to be $575,214,000 in 1959: "Tourist Survey for 1959" - A Missouri Study by the Resources and Development Commission, conducted by Dr. Richard E. O'Brien, Industrial Section, (1960).

There are extensive Federal and State developments in the region that enhance recreational opportunities, and more are proposed. Two large National Forests, Clark and Gardner, are located in the Eastern Ozarks. The State of Missouri has acquired large acreages of forest lands, and has developed parks, camping sites, and many other facilities that are an attraction to the vacationist. Now there is being proposed through a bill to be considered by Congress the creation of the Ozark Rivers National Monument.

Under the provisions of this bill the Federal Government would purchase 113,000 acres of narrow riverbank strips, making possible further extension of management of the streams and woodlands for public enjoyment - increasing materially the substantial recreational provisions already made in these river basins of the Ozarks. Based upon experience elsewhere, the National Park Service estimates such a National Monument would within five years attract 800,000 new visitors annually who would spend $5.5 million for motels, restaurants and gasoline stations. Investments in such facilities from private sources it is estimated would add around $10 million to assessed valuations on county tax rolls. Such development would also tend to benefit the economy in many other ways and at the same time more firmly establish the recreational character of the future use of highland portions of these basins.

In addition to fish and wildlife propagation, and to recreation, the water resources of the region are used mainly for domestic or public and industrial water supplies, agriculture - such as stock watering, navigation - by canoes and fishing boats, and final disposal of wastes. Most of the municipalities depend on wells or springs for their water supplies. Rural supplies are generally obtained from shallow wells or springs.

In general, pollution of surface waters in the stream basins studied cannot be classed as extensive when compared to the more populated and industrialized areas of the State. Wastes from municipal sources and from some usually small-scale industrial establishments including meat and poultry packing plants, sand and gravel operations, ore processing installations, and milk processing plants, occasion problems primarily of a local nature.

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Figure 12. Black River near Highway W Bridge about seven miles north of Poplar Bluff, Missouri.

Figure 13. St. Francis River looking upstream from Highway 60 and Railroad Bridges near Fisk, Missouri.

Information concerning municipal and industrial waste facilities assembled under a cooperative State-Federal program is set forth in publications issued periodically by the Public Health Service, U.S. Department of Health, Education and Welfare 54/. Data concerning waste disposal appearing in the 1957 inventory brought up to date as far as possible for communities in the basins under consideration are presented in Table VI, appended.

The sewage and wastes from the small communities and the sparsely inhabited upland watershed areas apparently exert only a more or less localized demand on oxygen resources of the streams, being most evident during critical low flow - warm weather conditions. These periods are reported most likely to occur the latter part of the Summer or early Fall - with minimum flows usually being encountered during the months of August, September, or October 55/.

Reaeration characteristics of the streams, particularly in the upper portions of the basins, are generally very good. Even during the low water period existing at the time of the reconnaissance survey flows over gravel stream beds and rock strewn ledges, such as shown for the Gasconade and Current River Basins in Figures 8 to 11, tended to maintain dissolved oxygen conditions around saturation for existing elevations and temperatures.

The field determinations of dissolved oxygen during this survey (Appendix II) were considered to give reasonable indication of what might be expected for future low flow periods under existing basin conditions. Results were helpful in appraising available oxygen resources, a portion of which might be utilized for final mill effluent stabilization, in the studying of assimilative capacities of these streams.

Sections of the Black and St. Francis River Basins observed in the field work differed very much from the other Ozark streams. While it is understood their characteristics are similar to the others in the headwater portions, both rivers emerge from their rough, forested, high plateau headwater region and flow southerly through the relatively marshy, flat, Mississippi bottomlands. Spring fed and turbulent flowing in the upper reaches, both rivers assume the placid or quiescent flowing conditions, shown in Figures 12 and 13, during periods of low discharge in the Poplar Bluff and Fisk areas.

Two large water impoundment projects, provided primarily for flood control but involving also fish and wildlife and recreational interests, have been carried out in the Black and St. Francis River basins. In May, 1940, the Corps of Engineers started construction of the large earthen dam on the Black River to create Clearwater Lake. World War II temporarily halted construction, but work was resumed in May, 1946, and the Clearwater Dam was ready for use in the Fall of 1948.

Located approximately five miles southwest of Piedmont, Missouri, and forty-six miles upstream from Poplar Bluff, Missouri, the largest city in the Black River Valley, the dam has provided capacity for 413,700 acre-feet of storage for the runoff from 898 square miles of drainage area. Under normal operations, however, the water level is regulated to maintain permanent storage of 21,920 acre-feet for purposes of conservation and recreation.

The impoundment on the St. Francis River for flood-control storage and other purposes such as described for the Black River, is designated by the name of a nearby community, Wappapello Reservoir. The earth-fill dam creating this reservoir was completed in 1940, with total content of 1,034,000 acre-feet at maximum pool level to receive the runoff from 1,310 square miles of drainage area. Permanent storage of 38,600 acre-feet is provided for conservation and recreation purposes.

In the upper St. Francis River basin, a number of artificial lakes have been created for recreation. Included are Lake Killarney on Strouds Creek, Shepherd Mountain Lake, and Old and New Iron Mountain Lakes. The last two lakes were developed by the mining industry. With Missouri a leader among lead producing States, it is of interest to note that much of this lead comes from mines in St. Francois County. While some pollution in the upper basin is caused by mining wastes, it is stated that more serious pollution occurs in watersheds other than that of the St. Francis River. 57/.

Below the Clearwater Reservoir in the vicinity of Poplar Bluff on the Black River and between Wappapello Reservoir and Fisk on the St. Francis River, the abrupt transition in character of these watercourses takes place. Downstream from Poplar Bluff the Black becomes almost typical of the deep-south. The aquatic life changes. This is discussed further in Appendix III. The water itself appears to loose the clear, sparkling appearance characteristic of the upper reaches in the Ozarks. 58/.

Lowlands Area: Only a small portion of the Black River drainage area between Poplar Bluff and the State boundary line where the stream flows into Arkansas, is situated in the southeast Missouri lowlands. However, the St. Francis, along with its largest tributary, Little River, is the major watershed of these lowlands - which constitute part of the Mississippi River bottomlands.

In general, the land is low and flat, and mostly in cultivation. This use has been made possible by an intricate system of drainage ditches and canals. Water draining from the farm lands and remaining marshy areas is conveyed into these rivers influencing the quality of their waters as they flow South through the lowlands.

As reported for the Ozark upland portions of basins covered in this study, the ground-water situation is generally good in the area extending eastward into the alluvial Mississippi bottomlands. Supplies are indicated to be of ample quantity and of satisfactory chemical quality except for occurrence of excessive hardness in some localities. It is stated that considerable additional ground water can be obtained from wells to meet future needs, including such industrial use as for pulp and paper mill water supply.

In locating new pulp and paper mills there has been a tendency to give more consideration to availability of suitable supplies of groundwater to meet entirely, or in part, the needs for processing, cooling and other manufacturing purposes. For high-grade papers some of the usual quality requirements are softness, low iron and manganese content, freedom from suspended matter, low quantity of carbon dioxide, and relative freedom from organic matter and bacteria.

In the bottomland portions of the Black and St. Francis River basins in Missouri groundwater is available from Quartenary deposits or deeper deposits. Again indicating the need for basic data,very little information is recorded in published form as to the quantity and quality of such waters.

Most of the public and private water supplies in this area are obtained from such groundwater sources. The only large community in this area making use of surface water for municipal purposes is Poplar Bluff, which obtains its water from the Black River.

The quality of the water delivered for domestic and industrial use by the filtration plant is indicated by chemical analyses, as follows: Silica (SiO_2) - 5.0 ppm; Iron (Fe) - 0.1 ppm; Sodium (Na) plus Potassium (k) - 8.2 ppm; Calcium (Ca) - 27 ppm; Carbonate (CO_3) - 0 ppm; Bicarbonate (HCO_3) - 149 ppm; Sulfate (SO_4) - 15 ppm; Chloride (Cl) - 6.3 ppm; Dissolved solids - 150 ppm; Hardness as $CaCO_3$ - Total - 129 ppm and Noncarbonate - 7 ppm; and pH - 7.8. The turbidity of the river water recorded in plant operations varied from a maximum of 170 to a minimum of 20, with an average of 25 ppm. Chemical analyses were made by the Division of Health of Missouri. The municipal water treatment involves coagulation with lime and alum, sedimentation, rapid sand filtration and chlorination.

There are a number of improvement projects involving levees, floodways, drainage structures, channel modifications, etc., in the lowland portions of the Black and St. Francis watersheds that are either being carried out or planned for the future 59,60/. These are directed mainly toward flood control, but agriculture, fish and wildlife, recreation, water supply , pollution control, and other interests are involved. Accomplishments will undoubtedly exert an influence on area potentials for further industrial development.

Mississippi River Borderland

Consideration was given to four principal areas along the Mississippi River in this reconnaissance survey of potential mill sites. Two of these areas, New Madrid and Birds Point, are situated in the alluvial bottomland section of the River Borderland, while the other two areas, Cape Girardeau and Ste. Genevieve, are situated where the Ozark highlands extend northeastward to reach the Mississippi River.

New Madrid Area: The first of these areas considered along the Mississippi River was the portion of the bottomlands located around New Madrid and East of the New Madrid - Sikeston Ridge levee. In addition to the environs of New Madrid, the area included the lower reaches of the watershed tributary to the St. Johns Bayou drainage structure, with outlet into the Mississippi River about one-half mile upstream from the City of New Madrid. The St. Johns Bayou is a partially improved natural channel that provides the outlet for the many natural and artificial channels that form the drainage system for the 480 square miles of watershed located northeast of the City in New Madrid, Scott and Mississippi Counties of Missouri.

Figure 14. Mississippi River at New Madrid, Missouri. Water transportation is available for timber and wood products.

Figure 15. Cotton cropping; one of the principal agricultural uses of the Mississippi River borderland.

This drainage area is bounded on the East by the Birds Point - New Madrid set back levee, on the West by Sikeston Ridge, and on the northwest by the Commerce Hills. The basin is generally fan-shaped and about 40 miles long from North to South with a maximum width of 25 miles. Comprising a part of the West bank flood plain of the Mississippi River opposite and below the mouth of the Ohio River, the area is substantially devoid of relief with elevations ranging from 280 to 325 feet above mean sea level. The entire St. Johns Bayou drainage area is now protected by a continuous Mississippi River West bank levee which extends from the high ground near Commerce, Missouri, downstream to and below New Madrid.

Between this West bank levee and the river are the low, flood inundated bottomlands, inclusive of the Birds Point - New Madrid Floodway.

The area under consideration is covered to a depth of around 200 feet by recent alluvial deposits of sandy loams, clays, sands and gravels underlain by tertiary sediments. As previously indicated, the land near the river not under cultivation, is usually covered with trees. These trees are now being used for lumber or pulp wood and other forest products.

Some of the timber from these lands bordering the Mississippi is being transported by river to sawmills, such as at New Madrid (Figure 14), and the rest mostly by truck. Water transportation for both raw materials and products is one of the advantages afforded by locations of industrial establishments along navigable waterways.

The extensive agricultural use of the lands for such crops as cotton (Figure 15), is important to the economy of the area. Cotton is predominant. As much as eighty-five percent of the farms of the delta counties are cotton farms. It is reported that cotton is a major crop on more than 13,000 farms in southeastern Missouri.

Industries in the area are oriented considerably to agricultural developments. There appears to be interest, however, in securing greater diversity in production. There are a number of factors that should prove conducive to industrial growth other than water resources.

There is an ample quantity of water available from the Mississippi River to meet all anticipated needs for water supply and dilution of the used water from such manufacturing establishments as pulp and paper mills using modern methods for waste recovery and industrial water management. The area in question is below the mouth of the Ohio River, and the combined flow of the Upper Mississippi and Ohio River basins is available to meet foreseeable future requirements for such mill developments.

Some fairly good yields of groundwater have been secured at various places in this general area. For example, three municipal wells at Sikeston having depths of 392, 405 and 366 feet are reported to yield 375, 800 and 920 gallons per minute, respectively. 61/. The water delivered by the waterworks is of the following chemical quality: Silica (SiO_2) - 10 ppm; Iron (Fe) - .2 ppm; Calcium (Ca) - 34 ppm; Magnesium (Mg) - 8.5 ppm; Sodium (Na) plus Potassium (K) - 11 ppm; Carbonate (CO_3) - 0 ppm; Bicarbonate (HCO_3) - 158 ppm; Sulfate (SO_4) - 3.7 ppm; Chloride (Cl) - 7.6 ppm; Dissolved solids - 181; Hardness as $CaCO_3$ - Total - 55 ppm; Noncarbonate - 37 ppm; pH - 7.3; and Turbidity - 0.1 ppm; as determined from analyses by the Division of Health at Missouri. Treatment consists of aeration by spray and contact beds, rapid sand filtration, and chlorination, to provide potable water for domestic and industrial use.

Big Oak Tree State Park and recreation area is located upstream from New Madrid in the southern part of Mississippi County near the river. There are fish and wildlife interests in the river and adjacent waters, and commercial fishing is also carried out in the boundary waters.

Birds Point Area: This location is in the easternmost portion of Missouri across the Mississippi River from the mouth of the Ohio River and opposite the southern end of the State of Illinois. The area is situated in the delta land, with the topography, climate, and general character being quite similar to that described for the New Madrid area.

The present development is largely for agricultural purposes. A considerable part of the land under cultivation is still devoted to cotton raising, although this is approaching the northern limits of the cotton belt of the State. There were some sizable farm woodlands observed, as well as substantial stands of cottonwoods and other trees in the low lying lands

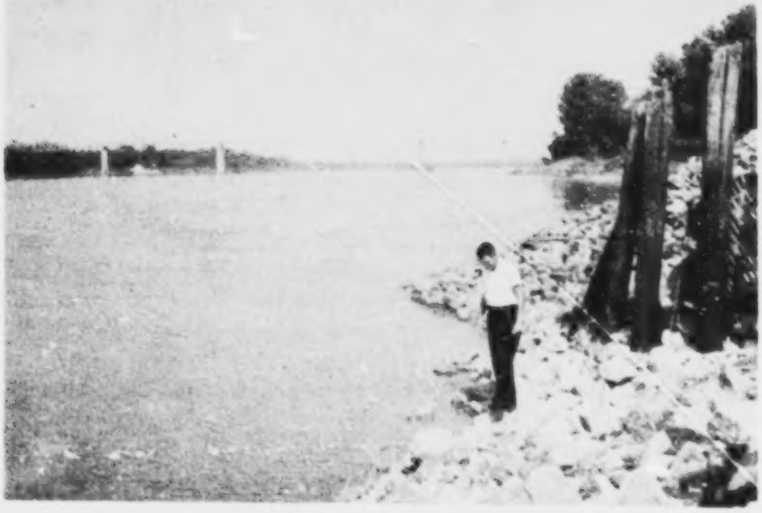


Figure 16. Mississippi River at Birds Point, Missouri. Good stands of Cottonwood, fastest growing of the area's timber resources, and other hardwoods suitable for pulping by modern processes, exist on the alluvial Mississippi bottomlands.

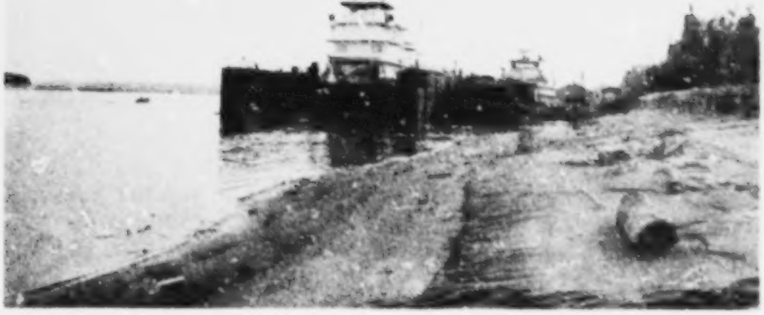


Figure 17. Mississippi River near Cape Girardeau, Missouri.

Figure 18. The Mississippi River is used for both private and commercial fishing: view near Interstate Bridge, Cape Girardeau, Missouri

Figure 19. Field tests of Mississippi River water at Wave Riders Boat Club pier near Ste. Genevieve, Missouri, made during reconnaissance survey of potential areas for location of mills.

near the river. Use is made of some of the larger timber. Small saw mills, such as visited at Wyatt, convert the logs into lumber. The River Borderland cottonwoods, as previously noted, are a potential source of supply of pulpwood for the production of mechanical pulp for newsprint and other paper products.

Essentially the same information as regards water resources and river uses as presented for the New Madrid area would apply to Birds Point, except that the flow in the river on the Missouri side of the stream would be that of the Upper Mississippi River. It would not, however, change the situation with respect to amount of dilution water available for any potential mill effluent.

Evidence of sport and commercial fishing activity along the river was observed near the interstate bridge at Birds Point while collecting water samples for field tests during the reconnaissance survey. See Figure 16. It has been pointed out from studies reported by Barnickol and Starrett 62/, that there has been a steady decline in the fishery resources of the river. They conclude that, "The principal factors limiting the Mississippi River fishery are related to soil erosion of the watershed, levee and drainage works, and industrial municipal pollution."

Cape Girardeau Area: There is a marked change in the character of the River Borderland Region in proceeding North from the Birds Point area to the Cape Girardeau area. The Mississippi River bottomlands terminate in the Commerce Hills, and the terrain becomes more rolling in crossing the Whitewater River Valley in approaching the City of Cape Girardeau. See Figures 17 and 18. The Mississippi shoreline changes rather abruptly where the eastern part of the Ozark highlands reach the river, forming the bluffs and the relatively high rocky promatory upstream from the business section of the City.

This municipality is the largest (population 24,947, 1960 census) located along the river in the area surveyed in southeastern Missouri. It is one of the oldest communities along the river, being established in 1793, and becoming an important shipping, milling and educational center during the early part of the last century. At present it is a shopping center for a fertile agricultural and dairying region, and the location of the Southeast Missouri State College. Industrial development includes manufacture of cement, shoes, clothing, electrical appliances and meat products.

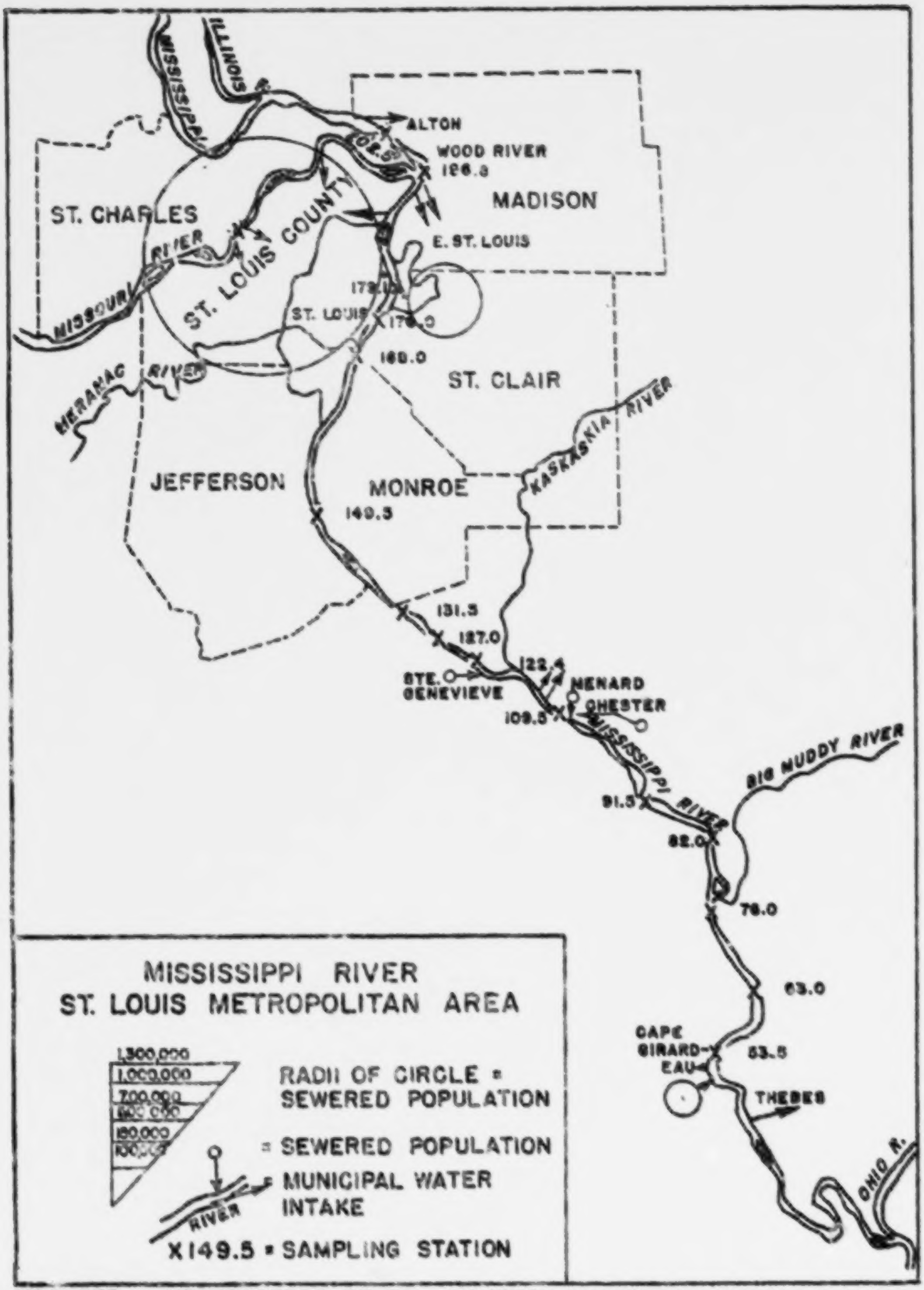
Areas suitable for further industrial development, including possible pulp and paper mill installations, are to be found near the City. Good highways radiate from the area into the more extensively forested parts of the Eastern Ozarks. Main North-South highways through the area, or which are readily accessible, provide trucking outlets to market. Also a toll free highway bridge crosses the Mississippi, providing direct connection with highways in Illinois. There are excellent railroad and waterways transportation facilities available (Figure 17) to serve the needs of industry.

The commercial fishing industry along the Mississippi River above Cape Girardeau, in the more than 115 miles stretch of water to St. Louis, has dwindled steadily. Factors considered largely responsible have been indicated, 63, 64, 65/. By 1950, it was reported by Starrett and Harth that due to increasing pollution, commercial fishing was almost non-existant from the St. Louis area to the mouth of the Kaskaskia River, 66/.

South of Cape Girardeau is the headwater diversion channel, or so-called Little River Diversion Canal. Extending West from the river toward the Eastern Ozarks through the Whitewater Valley, this canal was provided as a part of an extensive program for controlling the run-off from the watersheds comprising the "headwaters diversion" portion of the Mississippi River borderland in southeastern Missouri.

Water resources in the Cape Girardeau area include both the surface waters of the Mississippi and from the diversion channel drainage basin to the West. Groundwater is also available, with smaller communities in this basin being served with suitable supplies from wells.

Cape Girardeau gets its public water supply from the Mississippi River. Analyses, 67/, of the water after treatment have shown the following results: Silica (SiO_2) - 8 ppm; Iron (Fe) - .08 ppm; Calcium (Ca) - 63 ppm; Magnesium (Mg) - 20 ppm; Sodium Na) and Pottassium (K) - 17 ppm, Carbonate


ILLINOIS
MISSISSIPPI
ALTON
WOOD RIVER
196.3
MADISON
ST. CHARLES
ST. LOUIS COUNTY
E. ST. LOUIS
MISSOURI RIVER
179.1
ST. LOUIS
176.0
168.0
ST. CLAIR
MERAMAC RIVER
KASKASKIA RIVER
JEFFERSON
MONROE
149.5
131.5
127.0
122.4
STE. GENEVIEVE
MENARD
CHESTER
109.5
MISSISSIPPI RIVER
BIG MUDDY RIVER
91.5
82.0
76.0
63.0
CAPE GIRARDEAU
53.5
THEBES
OHIO R.
MISSISSIPPI RIVER
ST. LOUIS METROPOLITAN AREA
1,300,000
1,000,000
700,000
500,000
160,000
100,000
RADII OF CIRCLE = SEWERED POPULATION
= SEWERED POPULATION
= MUNICIPAL WATER INTAKE
RIVER
X149.5 = SAMPLING STATION

MAP III - MISSISSIPPI RIVER, SHOWING MUNICIPAL WATER INTAKES AND SEWERED POPULATION FROM ST. LOUIS, MISSOURI DOWNSTREAM TO OHIO RIVER.

(CO_3) - 0 ppm; Bicarbonate (HCO_3) - 173 ppm; Sulphate (SO_4) - 100 ppm; Chloride (Cl) - 20 ppm; Dissolved Solids - 364 ppm; Hardness - Total - 240 ppm; Noncarbonate - 98 ppm; pH - 6.9 and Turbidity - 1.4 ppm. These analyses, made by the Division of Health at Jefferson City indicate the chemical quality of the water that can be obtained from the river by treatment comprising coagulation, sedimentation, rapid sand filtration and chlorination. Even though water softening has been added and facilities for free residual chlorination have been provided, raw water pollution occasionally offers problems.

Cape Girardeau is the southernmost municipality in Missouri obtaining its public water supply from the Mississippi River. However, on the Illinois side, the small town of Thebes (population 471, 1960 census) takes its water from the river ten miles downstream from the intake at Cape Girardeau.

The character of the water reaching these intakes as well as those above at Chester and Menard State Prison in Illinois, is influenced by the sewage, industrial wastes and other pollution originating largely in the St. Louis Metropolitan Area 68/. Information on the locations of waterworks intakes in relation to sewered populations situated along the Mississippi River from the St. Louis Metropolitan Area downstream to the mouth of the Ohio River, taken from the most recent pollution survey report (1958) covering this stretch of the stream, is shown on Map III. 69/. This map also shows the location of water sampling stations, the figures being mileages above the mouth of the Ohio River. The two reports cited were prepared under cooperative programs carried out by the Bi-State Development Agency of the Missouri-Illinois Metropolitan Area, Division of Health of the State of Missouri, Sanitary Water Board of the State of Illinois, and Public Health Service, U.S. Department of Health, Education and Welfare. The initial studies were performed under the leadership of Mr. S. G. Monroe, involving nearly two years of field work in acquiring data on stream conditions, inventorying the nature and sources of pollution, and providing other pertinent information. The report on this work published in 1954, was supplemented and up-dated by further studies conducted by Mr. F. W. Kittrell and reported upon in 1958. These reports have been drawn upon in this study for data and information relating to water conditions at possible pulp and paper mill sites along the Mississippi downstream from St. Louis.

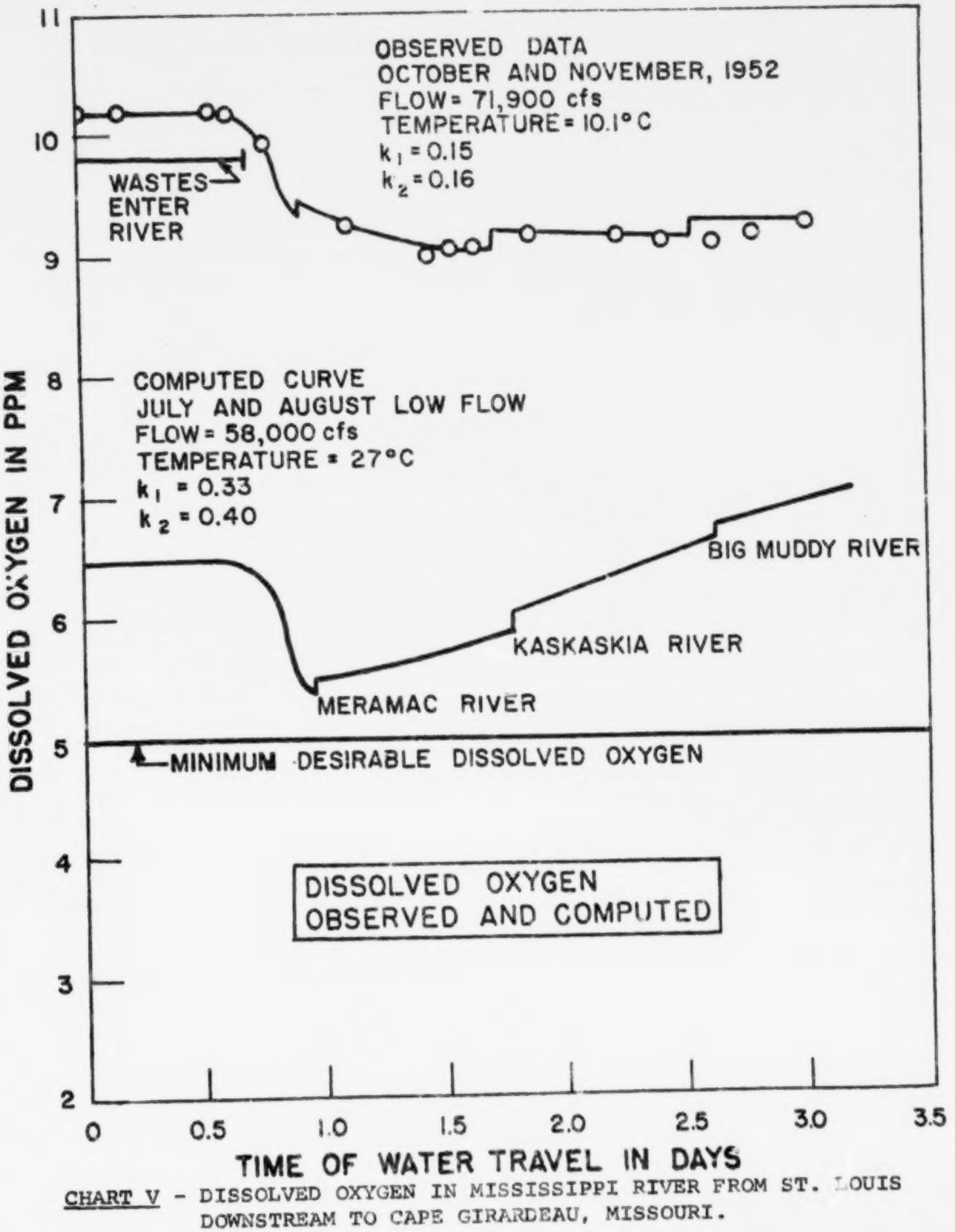


CHART V - DISSOLVED OXYGEN IN MISSISSIPPI RIVER FROM ST. LOUIS DOWNSTREAM TO CAPE GIRARDEAU, MISSOURI.

The impact of oxygen consuming wastes discharged in the St. Louis Metropolitan Area is substantial, as indicated by the oxygen sag curves developed from the above surveys and presented in Chart V. The upper curve was based upon 10 sets of stream samples collected during October and November, 1952, 8 of which extended downstream to Chester, Illinois, and 2 sets as far as Cape Girardeau. The lower curve was computed for the more critical July-August period of higher water temperature and low flows. The computed curve drops to 5.38 ppm of dissolved oxygen just above the mouth of the Meramec River, with the recovery zone extending downstream through Cape Girardeau.

It was emphasized in comments on this computed curve for the warm weather conditions that even though damage to fish by dissolved oxygen depletion is not indicated, assumptions made for conditions in 1958 were conservative.

The reports discuss in detail conditions caused by these pollutants. They will not be repeated here. Reference is made to the report for data and information on bacterial loadings, taste and odor producing substances, and other objectionable materials that are the result of pollution of the Mississippi River.

Ste. Genevieve Area: The character of the Mississippi Borderland in going North from the Cape Girardeau area is hilly, with high rocky bluffs to be found in some places along the river. In other places there are low bottomlands. One of the more scenic places along the shore that has been reserved for public recreational use is known as "Trail of Tears" State Park. There are a number of ravines, with small tributary streams discharging through them to the Mississippi. More woodlands are found and the farming trends more to dairying and fruit growing.

Ste. Genevieve, the earliest settlement along the river in Missouri, (1960 population 4,443), is the trading center for these surrounding farms. The interesting buildings and historical background of the community attracts a number of visitors, providing a local tourist business. There is some local use of the Mississippi for recreation, such as pleasure boating and water skiing, with the boat landing ramp and pier being shown in Figure 19. Major industrial development at present is quarrying of limestone, with large kilns being

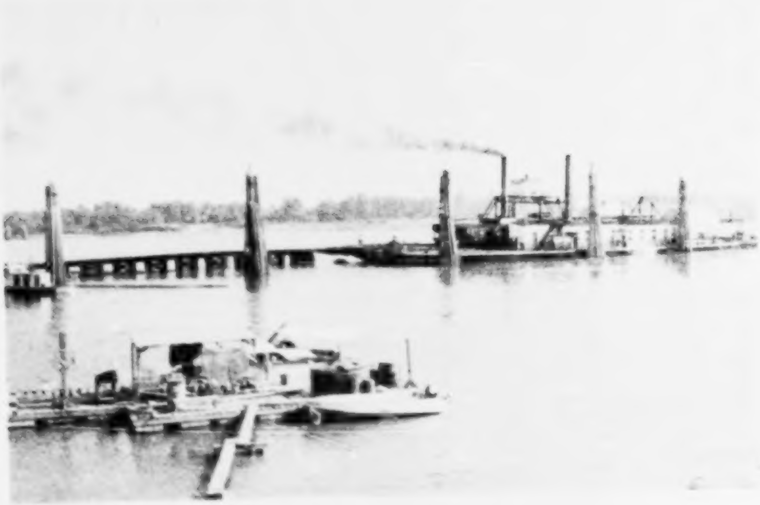


Figure 20. Missouri-Illinois interstate railroad ferry near Ste. Genevieve, Missouri; area furthest north along the Mississippi River included in the survey.

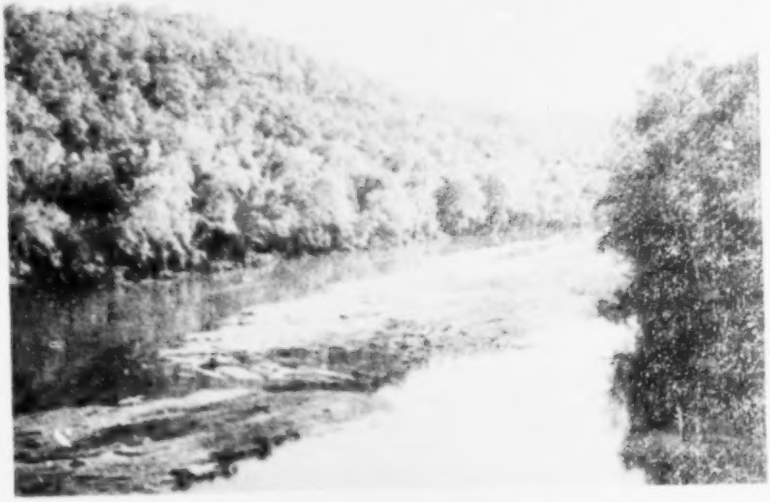


Figure 21. Big River at Highway 8 Bridge near Leadwood, St. Francois County, Missouri.

located nearby for preparation of lime for commercial purposes.

Good industrial sites are located convenient to railroad, highway and water transportation facilities. The railway car ferry, shown in Figure 20, provides connection with railroads to the East through Illinois. This along with rail connections North, South and West of Ste. Genevieve enable ready movement of manufacturing materials to mills and products to markets.

Ste. Genevieve does not use the Mississippi River for its public water supply. The community relies on two wells, the well with the greatest capacity (1.1 MGD) having zeolite water softening facilities. Accordingly, no data was available on the Missouri side of the river in this vicinity to show the quality of water obtainable from the river by usual methods of purification for municipal and industrial purposes.

Water tests in this survey, shown being performed by Mr. Fisher in company with Mr. Clair in Figure 19, as at Cape Girardeau, (Appendix II), gave results that conformed generally with computed dissolved oxygen values based on findings of earlier stream pollution studies. These were referred to under the previous subheading. In addition, tests made with three samples collected during July and August, 1957, at the Ste. Genevieve Ferry, shown in Figure 20, by personnel of the City of St. Louis Municipal Testing Laboratory have been reported to range from 5.5 to 5.8 ppm, with flows at St. Louis varying from 88,000 cfs to 221,000 cfs. 70/. These values were only 0.1 and 0.4 above the computed minimum for low flows and high temperatures. Water temperatures at the time ranged from 27° to 30°C, 71/. The computed sag curve shown in Chart V for a consecutive 7 day minimum flow occurring once in 10 years, 58,000 cfs, during the period of high water temperatures, 27°C, has accordingly been adopted and applied in the consideration of all potential mill sites from Ste. Genevieve downstream along the Mississippi River.

Until effective measures are taken to reduce sewage pollution upstream, particularly in the St. Louis Metropolitan Area, the Mississippi River water at Ste. Genevieve will continue to be of unsatisfactory quality for recreational purposes. Reported observations and analyses made in connection with the operation of waterworks at Menard State Prison and Chester, located on the Illinois side of the river about 14 miles downstream indicate difficulties in producing potable water from this section of the Mississippi, 72/.

It is significant also that during the meeting of Conferees on Pollution in the St. Louis Metropolitan Area, Mr. Jack Smith stated that on several occasions, industry seeking location in the midwest has advised the Division of Health that sites below the City of St. Louis could not be considered due to undesirable impurities in the water taken from the Mississippi. 73/.

While it is unlikely that pollution abatement measures in the St. Louis Metropolitan Area can be carried out as rapidly as may be desired due to the complexity of problems involved, there is good reason to anticipate from attention now being focused on these problems, that needed improvements will be forthcoming.

In view of existing circumstances, it was agreed to delete the section of the river between Ste. Genevieve and St. Louis from current consideration in this reconnaissance survey.

In proceeding West from Ste. Genevieve to the Meramec Basin, the route crossed Ste. Genevieve and St. Francois Counties, skirting the northernmost portion of the St. Francis River Basin in the vicinity of Farmington. The farms situated in this rolling terrain were noted to have more woodland pastures than elsewhere in the Mississippi borderland, and to the southwest of the highway to Farmington it was indicated that there are some fairly good stands of oak-pine forest suitable for pulpwood. These continue on into the Eastern Ozarks.

From Farmington northwest through the center of St. Francois County, there are a number of communities close together in the Flat River-Leadwood-Bonne Terre area. This is the most densely populated portion of the upland area of the Meramec Basin, which was entered near Flat River.

Meramec Basin: The only major stream which has its headwaters in the Eastern Ozarks that flows across the Mississippi River Borderland and discharges directly into the Mississippi wholly within Missouri, is the Meramec River. Its basin characteristics include those described for both the Ozark and River Borderland regions.

Detailed information concerning this basin has been set forth in "A Program for the Meramec River Basin (1949) - A Summary Report of the Meramec Cooperative Investigation Field Committee jointly prepared by agencies of the State of Missouri and agencies of the United States Government." This report with its eight separately published appendices, provided much helpful background in this study. 74/.

The basin is roughly rectangular in shape with the larger axis running generally East and West. It has a total drainage area of 3980 square miles. Bordered by the Lower Missouri River Basin on the North and West and by the Current, Black and St. Francis Basins to the South, with outlet to the Mississippi through the St. Louis Metropolitan Area, this highly diversified basin drains all or part of fifteen counties.

It is reported that 30 of the 34 public water supplies within the Meramec Basin are obtained from groundwater resources. Most of the farm supplies come from the same source, with some provided by springs that are found in a number of places throughout the area.

Following discovery by the French in 1700, the Meramec Basin gained international fame as a rich mining area. The valuable mineral resources found in considerable quantity were responsible for the early development of a mining industry still materially affecting the economy of the basin.

Farming and timber production are major industries in the basin. In general, the northern half has the more productive soil, but it is reported that the better soils for farming occur in the northeastern part of the basin where the surface is covered with a mantel of loess. The woodland pastures and forest covered areas increase toward the South. Orchards and vineyards are prominent in the basin; along with dairying, livestock raising, and the production of a variety of agriculture crops.

The considerable acreages of woodland, streams, springs, caves, and other natural attractions provide extensive recreational opportunities in the Meramec Basin. Parks, cabins, fishing clubs, hunting lodges, resorts, hotels and motels are scattered throughout the basin along highways and railroads furnishing ready access for thousands of vacationists from nearby St. Louis. The basin is appropriately called the 'St. Louis Playground'.

There are two principal tributaries to the Meramec River, the Big and the Bourbeuse Rivers. Of these, only the former was included in this study. A brief description of the Big River watershed follows:

Big River: This tributary is about 130 miles in length and enters the Meramec 35 miles upstream from the outlet into the Mississippi. The watershed has an area of 955 square miles and comprises the East side of the Meramec Basin. Rising near Brule, Missouri, the stream flows in a northerly direction along a winding course to its junction near Eureka with the Meramec.

The Big River for most of its length is relatively shallower and swifter than the Bourbeuse, with a gravel stream bed and numerous riffles. See Figure 21. Deep pools are reported in the extreme lower portion, and in addition, many fish dams and several old grist mill dams along the river tend to increase the time of flow by forming small pools serving as holding basins.

With the headwaters in the forest covered, granite sections of Washington, Iron and St. Francois Counties, the Big River drains the Bonne Terre - Flat River area that has continued over many years as one of the world's largest lead producers. This upper basin area has a wealth of lead, zinc and barite in residual, solution channel and filled sink deposits. In the vicinity of Potosi and Old Mines, most of the barite produced in this county has been mined in small diggings and large open strip pits. Numerous iron deposits in the area have been worked in pits and shafts, but the production has not been large. Mining operations produce the principal industrial effluents discharging into this upstream section of Big River.

In a 1943 pollution survey report on the Meramec Basin reviewed in this study, results of stream analyses on the Big and Bourbeuse Rivers, as well as on the Meramec were presented, 75/. Comparisons were made of alkalinity and hardness determinations, with the Bourbeuse showing the lowest values.

The comment was made that if low alkalinities had been the result of acid mine drainage or similar wastes, the non-carbonate hardness would have been much higher.

Dissolved oxygen results in Big River at that time ranged from 6.7 ppm (72% saturation) near the headwaters to 7.51 ppm (87% saturation) above the junction with the Meramec. Ample dissolved oxygen for fish existed then, as well as at the time of this reconnaissance survey, when above saturation conditions were determined under low flows in the stream near Leadwood, as indicated in Appendix II.

Meramec River. Rising in Dent County near Salem, the main stream of the Meramec flows generally northeast along a tortuous and meandering channel for 207 miles until it emerges as a flood plain stream emptying into the Mississippi about 20 miles below St. Louis. Where the upland creeks converge to form the Meramec, the elevation is 970 feet. The stream flows rapidly down through a trough in the Ozark Plateau along a course consisting principally of a series of shallow pools, riffles and sharp bends. In the portion of the watercourse below Steelville pertinent to this study, the average slope is about 4.6 feet per mile to Huzzah Creek, and from there through the St. Clair area to the junction with the Big River, the average slope is 2.3 feet per mile. From the mouth of the Big River to the junction of the Meramec with the Mississippi, the average slope is 0.9 feet per mile. It is reported that in the lower reaches the river widens, the pools are longer and deeper, and the flows are more sluggish.

The reaeration characteristics of the stream are very good in the upper and middle portions of the basin observed during the survey. The 1943 report on pollution previously cited indicated that dissolved oxygen determined at the testing stations along the stream gave results of 7.07 ppm D.O. (77% saturation) or higher. The alkalinity varied from 145 to 172 ppm.

At Kirkwood below the junction with Big River, the Meramec is used as the source of municipal water supply. The stream is also used as the source of supply for the South plant of the St. Louis County Water Supply System.

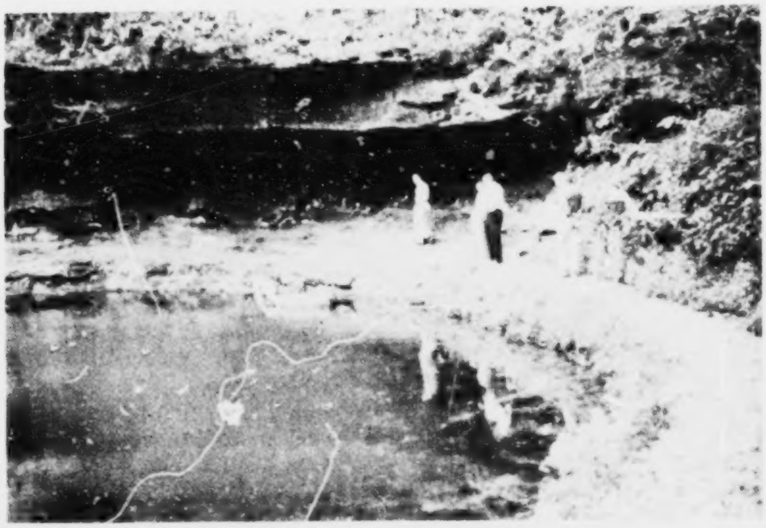


Figure 22. Meramec Spring, located six miles southeast of St. James, Missouri, largest of many springs tributary to the Meramec River.

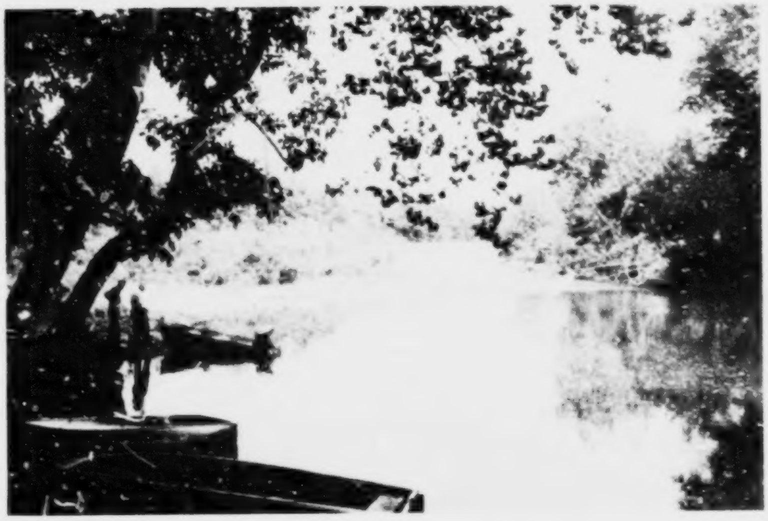


Figure 23. Meramec River near St. Clair, Missouri. Extensive use is made of stream for sport fishing and recreation.

In its upper reaches are found most of over 40 sizeable springs located in the basin, although some exist downstream as far as the vicinity of Eureka and Kirkwood in St. Louis County. The largest, Meramec Springs, is located in Phelps County in a park 6 miles southeast of St. James. See Figure 22. Its flow is reported to vary from 56 cfs during dry weather up to about 650 cfs during periods of heavy rainfall. The spring outlet is about 790 feet above mean sea level, with the water surging up in a circular basin, discharging over an old rock dam and flowing swiftly down the spring branch half a mile into Meramec River.

The cool, usually clear, spring waters are used in raising trout. These provide sport for the fishermen in the park. When the spring water joins the river, however, almost any type of native bass and other game fish are said to be available. In Appendix III, Mr. Funk has described the high quality of the fishery resources of this area.

According to a publication of the Missouri Conservation Commission*, "...For an unforgettable trip, put a boat in at the junction of Dry Fork and the Meramec and float to Meramec State Park. Along the way there will be plenty of white water for speed, deep, slow water for the leisurely casting of your fishing line, good camp sites, and a new landscape around every bend of the river."

The recreational use of the Meramec River Valley was evident in practically every place visited in the Steelville to St. Clair section of the waterway. Numerous summer cottages were observed - and these were only a small portion of the more than 8,000 reported to be located in the basin, 76/. Picnicing, swimming, fishing, boating, (See Figure 23), and other recreational activities and facilities were in evidence. It was apparent in the communities and along the highways that people in the area were endeavoring to provide a variety of accommodations and services to take care of the needs of the vacationist.

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* "The Rivers of Missouri", Pub. by the Missouri Conservation Commission, pp. 20, (1960).

Figure 24. Modern municipal sewage treatment works constitute an important part of State's water quality improvement program in Missouri: View shows Sikeston Plant.

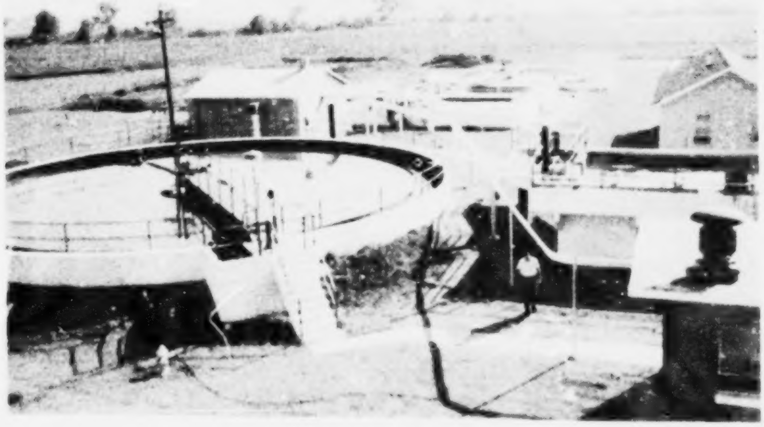

Figure 25. Complete treatment by the activated sludge process is provided at the Sikeston Plant.

It is evident from the foregoing and from additional information acquired that present developments and trends in the area would not give much encouragement to the location of industrial establishments in the basin. Both air and water pollution are involved, along with many other important considerations that go way beyond the matters covered by this report. It is of interest to note, however, that a new Meramec Basin Corporation has been organized to search out and publish the facts in an attempt to bring all considerations into focus in an unbiased manner, 77/. The present approach may lead to an acceptable program for future developments in the hitherto highly controversal Meramec Basin.

OTHER CONSIDERATIONS

The Missouri Water Pollution Board is conducting an agressive program to abate pollution of the State's streams. This program involves securing adequate treatment of all municipal sewage and industrial wastes consistant with local needs and downstream water uses. Emphasis is placed on keeping pollution from any new sources at the lowest practical minimum.

Modern municipal sewage treatment works affording a high degree of water pollution control, such as shown in Figures 24 and 25, were observed during the survey. Such treatment works, carefully maintained and operated, are doing much toward realizing the aims of the Commission. 78/.

In Table VI, appended, are presented data and information regarding treatment facilities existing at main sources of sewage pollution in the basins included in this reconnaissance survey, i.e., the Gasconade, Current, Black, St. Francis and Meramec Basins. The table does not include the Mississippi River communities involved in this survey, all of which have been discharging raw sewage into the river. Populations served by the sewerage systems, along with the type, design, and degree of treatment provided, and the watercourses receiving the effluents, are indicated. These facilities substantially reduce amounts of settleable solids, oxygen demanding materials, etc., that require assimilation by the streams being studied.

Cooperative studies on sewage lagooning have been conducted in recent years at Fayette, Missouri, by the Public Health Service in a program jointly sponsored and supported by the State

Figure 26. Oxidation Ponds are being used increasingly for both municipal and industrial wastes: Pond shown is in the Meramec River Basin near Sullivan, Missouri.

Figure 27. Lead and zinc ore processing wastes being discharged to a sedimentation pond, or waste impoundment basin.

of Missouri and the Service, under an agreement with the City. Results are now being increasingly applied in solving pollution problems. A typical installation of these so-called 'oxidation ponds' or 'waste stabilization lagoons' for effective, economic treatment of sewage and wastes, observed during the survey, is shown in Figure 26. There are a significant number of lagoons already operating in southeastern Missouri, as indicated in Appendix VI, and others are being installed.

Industrial wastes in the area are also being discharged to oxidation ponds in some situations, either in independently owned lagoons or joint treatment systems with municipalities. They equalize to a large extent fluctuations in waste loadings from any variations in industrial operations. Waste impoundment basins have been provided for removal of settleable solids, such as shown in Figure 27, for taking care of drainage from mining operations. All of these installations tend to increase the potentialities for further use of water resources for all purposes, including needs of industry.

Most of the water employed in manufacturing pulp and paper is returned to the watercourses from which it is obtained. Water is now usually conserved by recycling. Should it be possible to have complete consumption of the water, such as by providing land disposal for all of the processing waters instead of returning them to streams, there would be no particular question as to limits for mill production based on dilution and available oxygen resources. It should be added, however, that if land disposal is employed, care must be taken that there be no damage to uses of underground waters.

The size of mill which may be constructed at a definite site depends largely on (a) how much pollution can be 'built out' of the processes employed, and (b) the waste treatment and effluent disposal control facilities that can be applied. The more materials a mill can retain in-plant, or reclaim as byproducts, and the more that 'left-overs' in the process waters discharged can be removed or treated, the greater the mill production that may be provided without exceeding the limits of use of effluent assimilative capacity of a stream as defined by regulatory requirements.

This means for instance that if reasons develop for raising the minimum dissolved oxygen content above the 5 ppm used as a limiting value in these studies for critical conditions of low flows and warm weather, either production capacity would need to be restricted, or additional removals of oxygen demanding substances would need to be provided. In the latter case, if waste stabilization lagoons were utilized, it would mean enlargement to provide greater detention periods for reducing the over-all effluent oxygen requirements. Other biological waste treatment processes, such as illustrated in the drawing in Appendix X, might provide the answer. While there is flexibility possible in meeting more exacting needs by using these methods, there are practical limitations that will require special consideration in connection with any specific mill project proposed.

The aim is to continuously maintain satisfactory stream water quality for all legitimate water uses, such as domestic and industrial water supplies, aquatic life propagation, irrigation, stock watering, and recreation, including swimming, boating and fishing. Normally if there is sufficient dilution available for the effluent from a properly designed and operated modern pulp and paper mill to assure the presence of an adequate supply of oxygen at all times in the receiving stream for aquatic life propagation, it is considered that the water quality would be suitable for other water uses. The only apparent exception would be a taste and odor problem with drinking water supply obtained a short distance downstream. As regards kraft mill and other pulping processes considered, the oxygen consideration would be more critical than any toxicity factor in the receiving waters.

In proceeding with the estimation of mill capacities that could be supported by the various streams studied from the point of view of water pollution, the plan considered most suitable was to evaluate the maximum amounts of biochemical oxygen demand (B.O.D.) that may be discharged by mills if located at sites suggested along the designated streams. In each specific situation indicated in the discussion of mill sites, the quantity of oxygen demand presented should not be exceeded if desired river water quality is to be maintained during critical late summer and early Fall months. Approximations of mill capacities, based on considerations previously discussed under the section on mill effluents, have been made in keeping with the indicated maximum amounts of oxygen demand for the different possible mill locations along the streams.

Variations in maximum mill capacities presented could develop as a result of improved process design, waste treatment facilities, alterations in the quality and amounts of dilution water available, and some other factors. It is anticipated several pulping processes may be used in some mills using Missouri pulpwoods, with probable integration of chemical recovery processes, along with different types of paper production. It is accordingly advisable to re-appraise the water pollution situation in every case based on the particular processes and waste control measures specially planned for each mill.

In computing the above information it is fundamental to have as complete information as possible on stream flows. The various records previously mentioned have been drawn upon extensively in this reconnaissance survey. While low flow conditions are of primary interest, the lowest stream flow of record may not be the correct value to use due to the water temperature - dissolved oxygen relationships involved. Accordingly, it was considered best to make computations based on the dilution water that would be expected to be available during the lowest 7 consecutive day period of the critical month that would be expected to occur once in 10 years.

In two of the basins studied, the Black and St. Francis, there have been substantial changes in water flows in the portions of the basin below the Clearwater and Wappapello reservoirs, respectively. Since areas for consideration as mill sites were below these impoundments, only recent flow records obtained since completion of the reservoirs were used for the Black and St. Francis Rivers. In other basins all available records were used.

Under the following headings are presented the pertinent details and summations in the appraisal of the proposed mill sites from the point of view of effluent effects on stream water quality.

MILL SITES

Gasconade River Sites

The sites in the initial basin visited, the Gasconade, have a definite potential for location of a pulp and paper mill. The river sectors involved are (1) from the vicinity of Rich Fountain to the junction with the Missouri near Herman, Missouri, and (2) from Jerome to Rich Fountain. Special basin conditions pertinent to the study are as follows:

The critical month for the Gasconade Basin was determined to be September. The mean annual temperature in the basin is about 55°F. (13°C.) with an ordinary range from 22°F. above zero (-6°C.) to about 90°F. (32°C.). River water temperature can be expected to vary from around 36°F. (2°C.) to about 80°F. (26°C.). The normal annual precipitation varies in different parts of the basin from 36 to 44 inches. The average annual run-off is about 14 inches. The combined flow of many springs maintains an unusually high discharge in low-water seasons.

Flow data for the Gasconade River used in these studies were obtained from records of USGS Gaging Stations near Rich Fountain and at Jerome, which are situated 53 and 107 miles from the river mouth and have drainage areas of 3180 and 2840 square miles, respectively. The records reviewed for Rich Fountain (Elev. 553.70 ft.) start with October 1921, and for Jerome (Elev. 657.64 ft.), with October 1923; extending through September 1960. The minimum flow of record at Rich Fountain is 271 cfs (September 19, 1954), and at Jerome, is 254 cfs (September 21-22, 1956; the lowest mean discharge for seven consecutive days at the former, 282 cfs during 1954, and at the latter, 266 cfs, during 1956. No flow regulation exists even though at least four dams and reservoirs, two above Jerome and two between Jerome and Rich Fountain, have been previously proposed.

Presented in Table VII, appended, are results of oxygen determinations and certain other sanitary analyses made with samples of the Gasconade River water collected at the lower end of the basin over a period of one year. Though these oxygen determinations were made in 1950 in connection with Missouri River Basin studies, results may be considered reasonably representative of conditions existing at the time of this survey. These results show a high degree of oxygen saturation.

Most of the discharges of oxygen consuming pollutants that require assimilation by the stream are situated in the headwaters area well above Jerome. Where such pollution problems exist, they are indicated to be mainly local in nature. Residual effects of municipal treatment plant effluents, indicated in Table VI, appended, and other discharges appear to be largely taken care of by upstream oxidative resources. With numerous riffles and pools along its winding course, the river has good natural stream purification characteristics.

The good sanitary quality of the water discharged into the Missouri River at the time of sampling was further indicated by bacteriological results. It is further reported that suspended sediment is small when compared with that of other major streams of the Missouri system. It appears from all data available that ordinary water purification facilities would suffice to produce an excellent water supply for both municipal and indistrial purposes, inclusive of a supply meeting pulp and paper making requirements of TAPPI, 53/, 80/.

A further guage of the prevailing stream quality is the report furnished by Mr. Funk of the type of fishery resources, Appendix III, that are found in the sectors considered along the Gasconade. It is pointed out that the high proportion of game fish among the important species and the relatively low proportion of rough fish are indicative of a fishery of high quality.

In order to provide suitable protection for fishery resources and for other stream uses, waste control facilities provided at any mill that might be located in this basin should include waste impoundment facilities and effluent monitoring to regulate discharges to the stream, particularly under critical low flow - warm weather conditions. Indicative of low stream flow duration conditions to be considered in providing such facilities are data presented in Appendix IX. There are a number of adequate areas for such impoundments in the 'ox-bow' bends of the river in both sectors under consideration, and conditions are particularly favorable in the sector below Rich Fountain, where the valley gradually widens from about three quarters of a mile to around one and one-half miles at the mouth. Conditions would be favorable for installation of sizable waste stabilization lagoons. Effluent diffusers would need to be provided to assure good dispersion with stream flow.

The first Missouri River source of public water supply below the mouth of the Gasconade River is 75 miles downstream at St. Charles, Missouri. Dilution afforded at the junction with the Missouri River is ample and the distance of travel is great enough to exclude taste and odor problems in downstream municipal supplies.

Recreational assets of the region would need to be adequately protected in any future installation of a mill in this area. It is assumed that modern equipment to control atmospheric pollution would be provided, and other precautions taken to minimize changes in environment near the mill.

A waste discharge of 5600 pounds of 5 day B.O.D., 21°C, per day would be the maximum amount that may be discharged to the Gasconade River between Jerome and Rich Fountain without imparing the quality of water for other uses. This loading would be equivalent to an 80 ton per day semi-chemical, or hardwood kraft, pulp mill equipped with a modern chemical recovery system, with provision for converting the pulp into paper products. Estimates for integrated neutral sulphite and hardwood kraft pulping processes, with combined recovery systems, would indicate about the same over-all production capacity. A similar maximum safe loading of 6400 pounds of 5 day B.O.D., 20°C., that could be discharged to the stream sector below Rich Fountain would be equivalent to a 90 ton per day semi-chemical, or hardwood kraft, pulp mill with a modern chemical recovery system, and accompanying paper production.

Using the cold soda process with mixed Missouri hardwoods for producing unbleached pulp, the equivalent mill capacity that may be provided in the Jerome-Rich Fountain sector is 75 tons per day, and, in the sector from Rich Fountain to the mouth of the Gasconade, 85 tons per day. If the pulp is utilized in making newsprint, the capacities in sectors indicated would be reduced to 70 and 80 tons per day, respectively. With paper products requiring high quality bleached cold soda pulp, the above capacities would be further reduced to 55 and 65 tons per day.

For reasons previously indicated, it is unlikely that groundwood pulp would be produced initially at a mill located along the Gasconade River. Future increases locally in growths of softwoods that can be used for mechanical pulping might change this situation. In any event, the oxygen demand of processing waters discharged is low, and later addition of groundwood pulping could be taken care of by clarifiers and waste stabilization lagoons.

Current River Sites

The two sectors of the Current River considered in this study were (1) from the mouth of Jacks Fork near Eminence to Van Buren, and (2) from below Van Buren and Big Spring to the vicinity of Highway 160 bridge near Doniphan. Exceptionally good water resource conditions exist in the Current River Basin. With the flows from the large natural underground reservoirs underlying the Ozark Plateau entering the river from a number of very large springs augmenting surface run-off, the flows in this stream during periods of drought are quite high. Even under the very severe drought of 1936, the run-off during August was .467 cfs per square mile of drainage area above Doniphan, Table IV, appended.

Flow data for the Current River used in this survey were obtained from records of USGS Gaging Stations near Eminence, (Elev. 568.82 ft.), at Van Buren, (Elev. 442.78 ft.) and at Doniphan, (Elev. 322.21 ft.), which are situated 123.0, 90.4, and 51.3 miles from the junction with the Black River in Arkansas, and have drainage areas of 1,272, 1,667, and 2,038 square miles, respectively. Records reviewed from these gaging stations covered the period from 1921 through September, 1960. The minimum flow of record for Eminence is 324 cfs (October 7, 8, 1956), at Van Buren is 473 cfs (October 7, 8, 1956), and at Doniphan is 852 cfs (October 8-19, 1956); the lowest mean discharge for seven consecutive days at each station in the above order, being 334, 479 and 852 cfs, during October 1956. The critical month, however, is September. There are no existing regulation facilities for river discharge involved to influence stream flow characteristics in this basin.

Climatological data and other information for the area under consideration indicate that stream temperatures will usually vary from around 38°F. (3°C.) to about 76°F. (24°C.). Due to the relatively high proportion of spring water entering the river during low flow periods, comprising as much as 62% of the flow, (Table IV, appended), the uniform temperature of the spring water, 58°F. (14°C.), exerts an appreciable influence on water temperatures in stream sectors under consideration during the periods of low flow and warm weather occurring in the late summer and early Fall months.

Above the outfall of the public sewerage system at Doniphan, Table VI, Appendix VI, there are no other such systems located in the basin. The area is sparsely populated and has relatively few small, scattered industries. The only upstream community directly bordering the river is Van Buren. Sewage disposal is largely through septic tanks and other private facilities. There is practically no use at present of the assimilative capacity of this stream for effluents above the location where untreated sewage discharges at Doniphan.

Under the circumstances, and judging from similar conditions elsewhere, it can reasonably be assumed that dissolved oxygen in the river sectors indicated will be at or very near saturation. Validity of this assumption is indicated by analytical results during this survey, Table III, Appendix II. Because of the impact of the spring on water quality during low flow conditions, particular attention was given to the oxygen content of these ground waters. The oxygen content in each case was around saturation.

The good chemical and physical quality of the water available from the springs is further indicated by analytical results for some of the major springs of the basin, given in Table V, Appendix V. Up to the time of the survey, no public or industrial supplies have been developed utilizing waters of the Current River in Missouri.

The nearest downstream source of public water supply is that located at Pocahontas, Arkansas, six miles below the junction of the Current River with the Black River. The intake is 57 miles distant by river from Doniphan. This distance along with dilution by the combined flows of both the

Current and Black Rivers, taken into consideration with other factors, should make it possible to prevent any taste and odor problems from a mill effluent discharged in the designated sectors of the Current River.

This again assumes that effluent regulatory facilities, such as previously described for possible mill locations in the Gasconade basin, would be provided and carefully operated at any mill that might be situated along the Current River. Waste stabilization lagoons, for providing protection for the high quality fishery resource normally found in this stream as described in Appendix III, and other values, would be one of the main effluent control items to be considered if and when a definite mill project is proposed.

The water resources of the Current River in (1) the sector from below the mouth of Jacks Fork near Eminence, to Van Buren, Missouri, could take care of a maximum loading of 8400 pounds of 5-day B.O.D. equivalent to a 120 ton semi-chemical, or hardwood kraft, pulp mill, with chemical recovery system, and accompanying paper production; or (2) in the sector from below Van Buren and Big Spring to the vicinity of Doniphan, Missouri, could take care of a maximum loading of 16,700 pounds of 5-day, 20°C., B.O.D., equivalent to a 240 ton per day pulp and paper mill employing the above hardwood pulping processes. As indicated previously, estimates using integrated neutral sulfite semi-chemical and hardwood kraft pulping processes would result in approximately the same maximum over-all daily mill production figures for the above two sectors of stream, i.e., 120 and 240 tons per day.

Employing cold soda pulping for mixed hardwoods without bleaching, the equivalent mill capacity would be 110 tons per day for the Eminence-Van Buren sector, and 220 tons per day for the Van Buren-Doniphan sector; and, with bleached pulp production, 90 and 185 tons per day, respectively. Assuming use of the cold soda pulp for newsprint manufacture, the above capacities would be 105 and 210 tons per day for such combined pulp and paper production. In the event that paper products made with the cold soda pulp requiring substantial bleaching, the corresponding capacities would be further reduced to 85 and 165 tons per day.

The same situation as regards groundwood pulp production described for the Gasconade River sites would also likely apply for the Current River sectors studied. With continued good forestry practices, there should be continued increase in softwood that might be utilized for making this type of pulp. It is probable that chemimechanical pulping would be considered first in connection with any mill installation in this area.

As previously pointed out, the smallest economic size for a semichemical and groundwood pulp mill is about 50 tons per day. Since for best results semichemical and groundwood pulps should not be allowed to dry before processing into paper products, any such pulping operations would be expected to be proposed only as a part of an integrated pulp and paper mill project.

While development of several sites may be proposed, capacities should be kept well below the above estimated capacities for the two stream sectors, otherwise the stream may not be able to assimilate the wastes from the several mills.

There are quite important considerations aside from the water resources as regards mill locations in the area. As previously indicated in this report, substantial provision has already been made toward development of the recreational potentialities of the basin. State parks, camping and picnicing sites and various other such places have been set aside for public enjoyment. Provisions are being made to accommodate the vacationist. This scenic wonderland is attracting national attention in the proposal to acquire riverside areas for a National Monument. These existing and proposed park and recreational developments augur strongly against mill developments along the Current River.

Black River Sites

The only portion of the Black River Basin considered in this reconnaissance survey is the area in the vicinity of Poplar Bluff. The general characteristics of the stream as it emerges from the Eastern Ozarks and flows through the lowlands into Arkansas have been described. Climatological conditions upstream from Poplar Bluff are practically the same as for the Current River Basin, but downstream from Poplar Bluff they are more typical of the Mississippi lowlands. Monthly average river water temperatures in this downstream portion will vary from about 40°F. (4°C.) in January to around 78°F. (26°C.) in August.

Low flows in this basin are influenced both by springs and by operation of the Clearwater Dam and Reservoir. The large springs, while providing benefits similar to those described for the Current River, are fewer in number and their flows are comparatively much smaller.

Flow data were obtained from records of the USGS Gaging Stations near Leeper (Elev. 428.51 ft.) and at Poplar Bluff (Elev. 317.38 ft.), which have drainage areas of 957 and 1,245 square miles, respectively. Records available for Leeper cover the period June 1921 to September 1960, but only that portion of the data following the placing of the Clearwater Dam and Reservoir in operation have been utilized in this study. Similar records for Poplar Bluff, that is, following 1948, have been employed. The minimum flow at the latter gaging station, after regulation went into effect, was 241 cfs October 2, 1956 and the lowest mean discharge for 7 consecutive days was 249 cfs. The flow data at Leeper were used only for background in ascertaining the impact of regulation on low flows at Poplar Bluff.

When water is drawn from lower portions of reservoirs, it is not uncommon for dissolved oxygen to be low. This is particularly to be expected when organic wastes enter upstream. Good opportunity for reaeration is afforded in the fall of over 110 feet along the watercourse from Leeper to Poplar Bluff. Any oxygen deficiency in water released from storage, therefore, does not appear to be an important factor as regards the assimilative capacity of the river in the vicinity of Poplar Bluff.

Reference to Table VI shows three sewage stabilization lagoons are being utilized for the treatment of sewage and wastes at Poplar Bluff. Upstream there appears to be relatively little pollution of the Black River by oxygen consuming wastes. Spring waters entering should be at or near saturation.

Accordingly, the dissolved oxygen should be high even during periods of warm weather and low flow.

Analyses made during the critical month of September when this survey was conducted, results of which are given in Table III, Appended, support this view. It was assumed, therefore, that there would be good oxygen resources within the limits of flows available to assimilate the effluent from a mill located in the vicinity of Poplar Bluff.

The effluent from any mill in the area under consideration would undoubtedly be discharged below the municipal waterworks intake at Poplar Bluff. Otherwise there may be taste and odor problems. The nearest downstream public water supply obtained from the Black River is at Pocahontas, Arkansas, a distance of 120 miles by stream. Accordingly, there should be no difficulties due to tastes and odors in this situation.

In Appendix III, the quality of the fishery resources of the Black River is indicated. It is stated that there are a high proportion of rough fish found in the lower Black River, with only a limited number of sport fish showing up in the fish population studies. To protect this fishery resource, however, it is anticipated that suitable provisions would be made for monitoring and controlled release of effluents of any mill located in this basin.

For sites near Poplar Bluff, Missouri, it is estimated that the maximum quantity of 5-day, 20°C. B.O.D., that may be assimilated by the Black River would be 4,500 pounds, equivalent to a 65 ton per day semichemical, or hardwood kraft pulp mill, or kraft integrated with NSSC pulp mill, with chemical recovery and paper production; with the provision that the mill effluent would be discharged below the municipal water works intake at Poplar Bluff.

Utilizing the cold soda process with mixed hardwoods producing unbleached pulp, the equivalent mill capacity would be 60 tons per day and for bleached pulp, would be 50 tons per day. With the pulp for corrugating board, or liner board, the equivalent mill capacity would be 55 tons per day.

There might be increased production with the addition of pulp produced elsewhere, but the total effluent oxygen demand for products to be manufactured in any proposed mill project should be kept below the above limiting value for the stream assimilative capacity of the river in the vicinity of Poplar Bluff.

Groundwood pulp might possibly be proposed to make use of bottomland cottonwoods and other available woods that can be utilized for mechanical pulping. If the assimilative capacity of the stream were used entirely for groundwood pulp and paper production, the equivalent mill capacity would be 450 tons per day.

As with the other sites previously discussed, the effluent control and stream monitoring facilities should be a definite part of any specific project that may be proposed for this area.

St. Francis River Sites

The area in the St. Francis River Basin suggested for consideration for a pulp mill location is East of Poplar Bluff in the vicinity of Fisk, Missouri. The river has the longest watercourse within the State of those included in this survey, has its source near the highest point in the State and enters Arkansas at the lowest point, the flow is the least dependable for purposes intended. As indicated previously in this report, one of the main differences in the St. Francis Basin is that surface runoff is not augmented by flows from large springs. Despite storage provided in Wappapello Reservoir, and controlled release, the flows drop to 40 cfs and lower for long periods during warm dry weather.

Records of the Wappapello, Missouri, USGS Gaging Station show no flow for one day in 1952, Appendix VIII, and also for part of each day May 16, 1941 and August 31, 1954, as a result of closure of outlet gates at the dam. Even with storage afforded by the reservoir, there appears to be little opportunity to augment low flows experienced during the late summer and Fall months.

The St. Francis River and tributaries are now used to assimilate effluents from a number of municipal sewage and waste treatment systems (See Table VI, Appendix VI). It is apparent that dilution water available for assimilating effluents now discharged, along with any future effluent reaching the main stream as it emerges from the Eastern Ozarks into the Mississippi bottomlands, is extremely limited during critical low flow warm weather conditions. Computations showed entirely inadequate oxygen resources to take care of anticipated biochemical oxygen demands for even a small groundwood pulp and paper mill effluent. It was accordingly concluded that the St. Francis River in the vicinity of Fisk, Missouri, would have inadequate assimilative capacity to accommodate a pulp and paper mill of minimum capacity for economic operation.

Mississippi Borderland Sites

Pulp and paper mill sites in the Mississippi River borderland region of southeastern Missouri in the four areas considered offer the greatest potential for future mill installations judged from the point of view of effluent assimilative capacity of the river that might be made available and still stay well within limits of the water quality objectives now applying in the St. Louis Metropolitan Area; See Appendix I. Conditions existing in the New Madrid, Birds Point, Cape Girardeau and Ste. Genevieve have been described sufficiently in this report to indicate the quality of water supplies that might be developed for mill use, as well as the general characteristics of the four areas as they relate to possible mill locations in the river borderland region. The data and information that are available, particularly for the section of the river from St. Louis to the junction with the Ohio River, are much more adequate than for other streams included in this reconnaissance survey, but such basic data could be advantageously augmented by future expanded water quality studies in providing better aids or guidance for industrial and other developments.

Records of the gaging stations of the USGS maintained at St. Louis, Missouri (Elev. 379.94 ft.), Chester (Elev. 341.05 ft.) and Thebes, Illinois (Elev. 304.65 ft.), and Memphis, Tennessee (Elev. 183.91 ft.), have been consulted, but the flow and stream temperature data obtained in the St. Louis area is of most significance in view of the impact of existing pollution on oxygen resources and capacity for assimilation of effluents downstream. The minimum river flow of 27,600 cfs at St. Louis during the period 1928-1959 occurred during the winter (Appendix VII), when lowest flows were often noted to occur. The water temperatures usually ranged from about 32°F. (0°C.) to 86°F. (30°C.). In view of the temperature-flow-dissolved oxygen relationships, the July-August period was accepted as the most important for the purposes of this study. As previously indicated (Chart V) the flow of 58,000 cfs for a consecutive 7-day minimum occurring once in 10 years at a water temperature of 80°F (27°C.) has been utilized in computations of downstream assimilative capacities for effluents. Figures used might be increased progressively downstream from St. Louis, with increased flows in the Mississippi River because of waters entering from tributary streams, making due allowances for oxygen resources contributed, such as noted on the computed oxygen sag curve. However, the aim is to keep determinations on a conservative basis in this initial appraisal of possible mill sites.

In view of conditions indicated by Chart V, and also set forth in previous studies of the river cited in this report, it was decided to assume that only a small portion of the stream oxygen resources above the basic 5 ppm. limit that exists below St. Louis might be utilized in providing assimilative capacity for different types of mill effluents. From this small increment of over-all assimilative capacity, there have been determined equivalent mill capacities. This has been done in lieu of any specific requirements that now apply in connection with such developments as contemplated which might take place below the river sector covered by St. Louis Metropolitan Area water quality objectives.

Therefore, the mill capacities are only for the particular assumption indicated. They might be increased with allotment of a greater portion of the effluent assimilative resources of the stream. Such figures are based on the assumption that modern facilities for chemical recovery and recycling of processing water are applied at any mills installed. In general, the situation may be regarded as being less critical the further downstream any mill effluent is discharged below the St. Louis area, and particularly below the junction of the Mississippi and Ohio Rivers. The dilution available below the confluence of the two major rivers is indicated by the gaging station data at Memphis, where the minimum flow of record, occurring August 26, 1936, was 79,200 cfs. Even with this extreme drought flow, there would be much more assimilative capacity for effluents discharged at Birds Point and New Madrid.

Assuming it was permissable to allot 0.05 ppm. of the dissolved oxygen in the river water to satisfy the 5-day (20°C.) B.O.D. of effluents, under the flow and temperature conditions used in computing the sag curve in Chart V, it would be practical to assimilate the effluent from a 375 ton per day semichemical, or hardwood kraft, pulp mill, provided with a chemical recovery system, and conversion of pulp to paper products. The 375 ton daily production might be for a NSSC and hardwood kraft (1:4 ratio) pulp mill with integrated chemical recovery system and accompanying paper products. If unbleached cold soda pulp and corrugating board and liner board are manufactured in place of the above, the mill daily capacity would be 325 tons. Should it be desired to produce bleached cold soda pulp for use in making foodboards, or other varieties of papers and boards that can be made from such pulp, the mill daily capacity would be 260 tons. Groundwood or Chemigroundwood processes would probably be included at any mill built along the Mississippi River or in the borderland area. This would probably be done to utilize the cottonwood and other suitable local pulpwoods for integration with other pulping processes. The above indicated allotment of stream oxygen resources could take care of 870 tons per day of groundwood pulp produced with cottonwood.

It has been stated that "The Memphis area and other locations on the Mississippi River are favorably situated with respect to cottonwood lands, provide economic access to major markets via barge transportation for a distance of several thousand miles on the most interconnected inland-waterway system in the country, and are suitable in other respects for the establishment of initial newsprint mills based primarily upon cottonwood." 17/.

It is probable in making newsprint from hardwoods in Missouri that some of the pulp used would initially be bleached softwood pulps purchased or produced in other localities. If this is done, a newsprint pulp and paper mill using a furnish of groundwood made from cottonwood, cold soda pulp made from mixed hardwoods and purchased bleached softwood chemical pulp (12:3:5), could be installed having a capacity of about 300 tons per day.

It is obviously impossible to anticipate various combinations of processes that could be submitted in any mill project, but the above will give some idea of potentialities. Effluent control facilities should be provided, and above sources of municipal water supply, oxidative treatment would provide an additional factor of safety against taste and odors. Such treatment would also add flexibility in any mill development program.

Summarizing the situation on possible mill sites along the Mississippi River, the more critical area as regards dissolved oxygen resources of the receiving waters for effluents is upstream from Cape Girardeau to the St. Louis Metropolitan Area. The usability of the waters for municipal and industrial water supply has been impaired. The lower limit of 5 ppm. for dissolved oxygen* in the river is approached during August just above the mouth of the Meramec River. There is a gradual recovery of oxygen resources downstream, making it possible to provide for further controlled assimilation of effluents. With the trend toward pollution abatement in the St. Louis Metropolitan Area and downstream sewage treatment projects, along with future water quality management the potentialities of the Mississippi for increased reuse can be expected to improve.

From estimates previously indicated, it was concluded that the Mississippi River in areas near (1) New Madrid, (2) Birds Point, (3) Cape Girardeau, and (4) Sainte Genevieve, would be able to take care of effluents from each of the processes that might be employed for pulping hardwoods found in the river border area and Eastern Ozarks, with any mill having such daily capacity as might be considered economic for installation in these areas.

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* See Appendix I.

Meramec Basin Sites

The portions of the Meramec basin included in this survey have quite similar climatological conditions to those already described for the adjoining Gasconade River basin. The water temperatures will approximate those used in the studies of sites along the Gasconade. Low flows are augmented by springs, but the discharges from such sources, with the exception of Meramec Springs, can not be relied upon to furnish the relatively large flows that have already been described for the basins to the South.

Big River Sites

The flows in Big River were determined from the records of USGS Gaging Station located about 6½ miles West of DeSota, Missouri (Elev. 538.79 ft.), and situated downstream from the mill site area near Leadwood that was visited in this reconnaissance survey. The records indicated a minimum discharge of only 20 cfs on September 19, 1934. The stream flow based on the mean discharge that can be expected over a seven day period was only 26.4 cfs. This was considered to be well below the minimum low flow to support such a mill as might reasonably be considered for this region. In addition, the effluents from the other municipal and industrial developments (See Appendix VI) of the area would need to utilize a part of the available assimilative capacity of the stream.

Meramec River Sites

The records of flow for the main stream of the Meramec River were obtained from USGS Gaging Stations at Steelville (Elev. 681.68 ft.) near Sullivan (Elev. 581.82 ft.) and near Eureka (Elev. 406.16 ft.), with drainage areas of 781, 1475, and 3,780 square miles, respectively. The flow data given in Table VIII, Appendix VIII, indicate for the first two stations that low flows are not sufficient to provide assimilative capacity for an economic size mill, and only in the area below Eureka near the mouth of the river might future consideration be given to a mill installation. At present, it is understood developments in the lower river sector between Eureka and the junction with the Mississippi River would not be conducive to location of a mill in this area.

If a mill is situated at the mouth under present pollution conditions in the Mississippi River, the effluent would be discharged near the bottom of the sag curve shown in Chart V. The recreational developments and interests in this basin are also not regarded as favorable to industrial establishments along the Meramec River.

It is possible that by use of a joint municipal-industrial waste treatment project in the future developments of the pollution abatement program in and around the St. Louis Metropolitan Area, a mill waste treatment plan, such as described in Appendix X, might be applied.

As regards mill sites in the Meramec basin, both as to locations along the Big River and along the main stream of the Meramec, it was concluded as follows:

1. The Big River in the Leadwood-DeSoto, Missouri sector does not have the assimilative capacity needed to absorb the effluent from a pulp and paper mill of minimum economic size.

2. The Meramec River in the sector from Steelville to St. Clair is not satisfactory for receiving the effluent from a minimum economic size pulp and paper mill. Despite exceptional measures taken to minimize and treat any mill effluent, extensive recreational use of this river would make it undesirable to locate a mill along this section. Downstream from the indicated sector the river is used as the source for Kirkwood and St. Louis County water supplies.

In conclusion, observations and studies indicate that certain previously designated sectors of rivers included in this reconnaissance survey of possible pulp and paper mill sites would appear to have the capacity to satisfactorily assimilate the effluents from semichemical, or hardwood kraft, pulping processes, with chemical recovery, and integrated production of paper and paperboard products. This report needs to be considered as a preliminary appraisal of the suitability of the sites from the point of view of impact on water quality only. When a definite proposal is made for the construction of a pulp and paper mill at any specific location, there should be a detailed evaluation of conditions to be met in carrying out the project. Suitable operation and treatment provisions can then be determined for each proposal to enable attainment of a high degree of stream cleanliness consistent with water uses.

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U.S. Public Health Service

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APPENDIX

APPENDIX I

WATER QUALITY OBJECTIVES

The Engineering Section of the Missouri Basin Health Council, consisting of the chief sanitary engineers of the 10 Missouri Basin States, on January 7, 1954, adopted objectives as a guide for coordinated interstate water pollution control programs along the Missouri River. The guide has been employed by the State of Missouri in the development of its part of the comprehensive pollution control program, and was used as background information in carrying out this study. It is recognized that changes in conditions, particularly as they may affect water uses, and alterations in types of water uses, may require further modifications in any established objectives. The objectives adopted by the States of the Missouri Basin and used as a reference in this study are quoted as follows:

Missouri River:

"Subject to (a) such higher objectives as may be desired by any State and (b) such other modification as may be deemed necessary, after appropriate investigation, by the State Water Pollution Control Agency concerned, the Engineering Section, Missouri Basin Health Council, recommends the following for consideration by the member states as a guide for water pollution control activities in the Missouri Drainage Basin.

"1. Toxic substances including metallic ions, phenolic compounds, oils, alkalies, and acids should be virtually eliminated from sewage effluents.

"2. Removal of settleable and floating solids to prevent sludge banks, floating materials, and nuisance conditions should be required as the minimum acceptable treatment.

"3. For industrial wastes similar in nature to municipal wastes, treatment should be based on the same premise as recommended for municipalities. For industrial wastes not comparable to municipal wastes, treatment should be provided as necessary to prevent deterioration of water quality for beneficial uses in the receiving stream.

"4. Additional treatment over that specified in item 2 above should be provided as necessary to protect downstream water uses.

Quality objectives for certain water uses are:

"(a) For water serving as a source of domestic supply, raw water bacteriological quality should conform to that recommended in 'Manual of Recommended Water Sanitation Practices, 1946, Public Health Bulletin #296,' pages 11-13.

"(b) For bathing or swimming waters, monthly arithmetical average 'most probable number' of coliform organisms should not exceed 1,000 per 100 ml. during any month of the recreational season; nor exceed this number in more than 20 percent of the samples examined during any month; nor exceed 2,400 per 100 ml. on any day. For nonbathing or nonswimming waters, the monthly arithmetical average 'most probable number' of coliform organisms should not exceed 5,000 per 100 ml in any month of the recreational season, nor should exceed this number in more than 20 percent of the samples examined during any such month.

"(c) For fish and aquatic life a minimum oxygen concentration of 5.0 ppm is desirable in waters otherwise offering suitable fishery habitat, with 6.0 ppm for trout streams.

"(d) For bacteriological quality of irrigation water:

"(1) Sewage used for irrigation of forage crops should be given treatment insuring a consistent reduction in coliform bacteria of not less than 90 percent.

"(2) Sewage used for irrigation of human food crops should be given treatment insuring a consistent reduction (a) in suspended solids of not less than 75 percent, (b) in 5 day 20°B.O.D. of not less than 75 percent and (c) in coliform bacteria of not less than 98 percent, unless discharged into a stream where the volume of dilution water, available during the low flow periods during which irrigation diversions may occur, is at least 10 times greater than anticipated maximum daily volume of sewage, in which case a bacterial reduction of 90 percent may be acceptable.

"Provided, however, that where the time of passage from plant discharge to irrigation diversion is such as to permit the normal death rate of bacteria as evidenced by the die-away curve to provide equivalent bacterial reduction, the requirements of (1) and (2) above may be appropriately modified."

Mississippi River:

As a result of a pollution study of the Mississippi River in and downstream from the St. Louis Metropolitan area sponsored by the Bi-State Development Agency and conducted cooperatively with the States of Missouri and Illinois, and the U. S. Public Health Service during the period 1951-52*, the following water quality objectives were developed for the interstate waters and used in connection with further activities reported in 1958**, and as a basic reference in so far as this study is concerned with the Mississippi River:

General Objectives

"All wastes, including sanitary sewage, storm water, and industrial effluents, shall be in such condition when discharged to the Mississippi River that they will not create conditions in that stream which will adversely affect the use of those waters for the following purposes: source of domestic water supply or industrial water supply, navigation, fish, and wildlife, recreation, agriculture and other riparian activities."

"In general, adverse conditions are caused by:

A. Excessive bacterial, physical or chemical contamination.

B. Unnatural deposits in the stream, interfering with fish and wildlife, recreation, or destruction of aesthetic values.

C. Materials imparting objectionable colors, tastes or odors to waters used for domestic or industrial purposes.

D. Floating materials, including oils, grease, garbage, sewage solids, or other refuse."

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* "Mississippi River Pollution Investigation, St. Louis Metropolitan Area", Bi-State Development Agency, 1954.

** "Pollution of Interstate Waters of the Mississippi River in the St. Louis Metropolitan Area", Bi-State Development Agency, February, 1958.

Specific Objectives

"In more specific terms, adequate controls of pollution will necessitate the following objectives for:

A. Sanitary Sewage and Storm Water

"Sufficient treatment for adequate removal or reduction of solids, bacteria and chemical constituents which may interfere unreasonably with the use of these waters for the purposes aforementioned. Adequate protection for these waters would be provided by:

(a) Substantially complete removal of floating and settleable solids; and

(b) Removal of not less than forty-five per cent of the total suspended solids."

B. Industrial Wastes

(1) Chemical Wastes - Phenolic Type

"Industrial waste effluents from phenolic hydrocarbon and other chemical plants will cause objectionable tastes or odors in drinking or industrial water supplies and may taint the flesh of fish. Adequate protection should be provided for these waters if the concentration of phenol or phenol equivalents does not exceed a monthly average of 2 parts per billion and a maximum of 5 parts per billion at any point in these waters following initial dilution."

(2) Chemical Wastes - Other Than Phenolic

Adequate protection should be provided if:

(a) The pH of these waters following initial is not less than 6.7 or more than 8.5.

(b) The odor-producing substances in the effluent are reduced to a point that following initial dilution with these waters the mixture does not have a monthly average threshold odor number in excess of 10 and a maximum daily odor number in excess of 30.

(c) Oils and floating solids are reduced to a point such that they will not create fire hazards, coat hulls of water craft, injure fish or wildlife or their habitat, or will adversely affect public or private recreational development or other legitimate shoreline developments or uses. In order to accomplish this it will be necessary to reduce contrations of such materials discharged to the point where after initial dilution the stream shall be free of noticeable floating solids, oil, grease, and sleek."

(3) Highly Toxic Wastes

"Adequate protection should be provided for these waters if substances highly toxic to human, fish, aquatic or wildlife are eliminated or reduced to safe limits."

(4) Deoxygenating Wastes

Adequate protection of these waters should result if sufficient waste reduction process changes or if sufficient treatment is provided to accomplish substantially the same objectives as are herein set up for sanitary sewage...."

Guiding Views on Objectives

Communications on objectives in relation to this study have emphasized that the policy of the Missouri Water Pollution Board is to establish objectives for each stream based upon water quality requirements to meet various needs determined by water uses. While objectives have not been established for the tributary streams to the Missouri and Mississippi Rivers, the indication is that the above provisions, or more stringent requirements, could be expected to prevent detrimental effects in any multipurpose development of the inland waters covered by this reconnaissance survey.

It has been pointed out that the view of the Missouri Conservation Commission in administering forest, fish and game resources is that such water quality objectives as established for these streams adequately safeguard sport fishery, game, and other natural assets. To maintain such objectives the Commission advocated that the best known waste treatment practices for the waste waters from industry be provided, and even this might not be satisfactory insurance against damage to sport fishery. Operation and maintenance is important. It is further indicated that this is particularly true in the inland streams of Missouri where a high quality sport fishery of national reputation is concerned. Their feeling is that the provisions reviewed in this report would be minimal in the protection of the sport fishery and the game resource, and that such resources can be protected only through intensive planning for the most effective known treatment of wastes resulting from the pulp and paper industry.

APPENDIX II

TABLE III - WATER ANALYSES* - RECONNAISSANCE SURVEY OF POSSIBLE PULP AND PAPER MILL SITES IN SOUTHEASTERN MISSOURI

September 21-23, 1960

Sample No.	River Basin	Field Water Analysis Data
1	Current	Round Spring in Shannon County Date: 9-20-60 Time: 8:30 a.m. pH of the Water: 7.4 Water Temperature: 57 degrees Dissolved oxygen: 8.5 p.p.m.
2	Current	Alley Spring in Shannon County six miles West of Eminence Date: 9-20-60 Time: 10:40 a.m. pH of the water: 7.4 Water Temperature: 58 degrees Dissolved oxygen: 9.2 p.p.m.
3	Current	Big Spring in Carter County, four miles South of Van Buren Date: 9-20-60 Time: 1:40 p.m. pH of the water: 7.6 Water Temperature: 58 degrees Dissolved oxygen: 8.8 p.p.m.
4	Current	River, one mile above U.S. Highway 60 Bridge in Carter County Date: 9-20-60 Time: 2:20 p.m. pH of the water: 8.2 - 8.4 Water Temperature: 74 degrees Dissolved oxygen: 9.7 p.p.m.

Table III - Continued

5	Current	River at Highway 21 Bridge at Doniphan in Ripley County Date: 9-20-60 Time: 3:50 p.m. pH of the water: 8.2 - 8.4 Water Temperature: 73 degrees Dissolved oxygen: 9.7 p.p.m.
6	Black	River at Highway W Bridge near Hilliard in Butler County Date: 9-20-60 Time: 5:15 p.m. pH of the water: 7.8 Water Temperature: 74 degrees Dissolved oxygen: 8.4 p.p.m.
7	St. Francis	River at U.S. Highway 60 Bridge near Fisk in Butler County Date: 9-20-60 Time: 6:00 p.m. pH of the water: 7.4 - 7.6 Water Temperature: 74 degrees Dissolved oxygen: 7.3 p.p.m.
8	Mississippi	River at New Madrid, Missouri Date: 9-21-60 Time: 9:30 a.m. pH of the water: 8.2 Water Temperature: 76 degrees Dissolved oxygen: 7.1 p.p.m. Note: Sample collected near Ralph Anderson Lumber Company, Inc.
9	Mississippi	River at U.S. Highway 60 Bridge near Bird's Point in Missippi County Date: 9-21-60 Time: 2:15 p.m. pH of the water: 7.8 Water Temperature: 77 degrees Dissolved oxygen: 7.1 p.p.m.

Table III - Continued

10	Mississippi	River at Highway Bridge at Cape Girardeau Date: 9-21-60 Time: 4:30 p.m. pH of the water: 7.8 Water Temperature: 76 degrees Dissolved oxygen: 6.9 p.p.m.
11	Mississippi	River at Wave Riders' Boat Club Parking Area near the Missouri-Pacific Railroad Ferry near Ste. Genevieve Date: 9-22-60 Time: 8:15 a.m. pH of the water: 7.6 Water Temperature: 74 degrees Dissolved oxygen: 6.6 p.p.m.
12	Big	River at Highway 8 Bridge near Leadwood in St. Francois County Date: 9-22-60 Time: 10:45 a.m. pH of the Water: 8.2 Water Temperature: 74 degrees Dissolved oxygen: 9.0 p.p.m.
13	Meramec	River near St. Clair in Franklin County Date: 9-22-60 Time: 2:15 p.m. pH of the water: 8.2 Water Temperature: 74 degrees Dissolved oxygen: 10.2 p.p.m.
14	Meramec	River at Bird's Nest near Steelville Crawford County Date: 9-22-60 Time: 3:40 p.m. pH of the water: 7.2 - 7.4

Table III - Continued

15	Meramec	Meramec Spring East of St. James in Crawford County Date: 9-22-60 Time: 4:20 p.m. pH of the water: 7.2 Water Temperature: 59 degrees Dissolved oxygen: 7.4 p.p.m.

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*Analyst: Herbert J. Fisher: Above analyses were made of various waters enroute. The Hellige Comparator was used in obtaining pH readings, the Sodium Azide method was used in determining dissolved oxygen readings, and the Farenheit thermometer was used in obtaining temperature readings.

APPENDIX III

FISHERY INFORMATION ON STREAMS WHICH MAY BE SUBJECT TO POLLUTION FROM PULP MILLS OR OTHER INDUSTRY

John L. Funk
Fisheries Research Supervisor
Missouri Conservation Commission

Effluents of pulp mill or other industrial wastes can have a devastating effect upon fish. For this reason it is important in considering the location of an industry to avoid streams of recognized recreational quality. We refer particularly to this quality as it relates to the sport fishery. Research upon the fishery of Missouri streams which the Conservation Commission has done over a period of years provides a background of information by which their recreational significance can be established.

The streams considered here have been suggested as offering possible locations by pulp mills or other industries. These include the Lower Mississippi River in Missouri and the St. Francis, Black, Current, Gasconade, Meramec and Big Rivers. Although no new material is presented here for the Mississippi River, this document is supplemented by a report on the Mississippi River entitled "Commercial and Sport Fishes of the Mississippi River" by Barnickol and Starrett (1951) and the March, 1958, report on the Mississippi River prepared for the conference on water pollution held at St. Louis. No data are presented for the headwater portions of the other streams on the assumption that the water supply problem would prevent location of a pulp mill in a headwater area.

The information which is presented here is of two kinds. The first gives the composition of the fish population of specific areas of the streams under consideration. These data were obtained by combining the results of many collections made over a broad span of time. The second type of information gives the condensed results of a creel census conducted between 1950 and 1958.

Fish Polulation Data

The fish population data are presented as lists of species from 9 specific areas on the 5 streams under consideration. The lists were derived from numerous collections made at specific locations at different seasons in the late 40's and early 50's.

Electric shockers, hoop nets, and drag seines were used in making the collections, thus gear selectivity was minimized. The frequency of its occurrence in the collections, the total number, and the total weight of each species is given. These factors were used in a quantitative way to determine the species which were important in the area. These important species are the ones which will receive most consideration in our discussion.

Lower Black River (Table I)

This station is located on Black River near Hilliard (T25N, R6E, Section 16, Butler County) upstream from Poplar Bluff. However, its fish population probably is fairly representative of this section of the river. The important species include a high proportion of rough fish and the sport fish included make up a rather small part of this total number and total weight. A fishery of rather poor quality is indicated.

Table 1. Species taken, with frequency of occurrence, total number and total weight of each in 20 collections from the lower Black River Station, 1947-1953.

Species	Frequency of Occurrence (per cent)	number	Weight (pounds)
Spotted gar	5	1	0.6
Longnose gar	35	11	17.4
Bowfin	20	4	12.3
Mooneye	40	17	5.0
Gizzard shad*	90	669	292.6
Bigmouth buffalo *	25	8	29.0
Black buffalo *	25	9	29.7
Smallmouth buffalo *	25	10	28.5
River carpsucker	25	7	16.9
Blue sucker	5	1	5.0
Hog sucker	35	17	5.7
Spotted sucker	20	6	3.6
Black redhorse *	55	79	23.6
Golden redhorse *	75	318	120.5
Northern redhorse	45	23	18.5
River redhorse	25	6	20.2
Moxostoma sp.	30	21	10.7
Carp *	70	33	123.4
Channel catfish *	60	33	44.0
Black bullhead	15	3	1.3
Flathead catfish *	75	35	153.7
Stonecat	5	1	0.1
Grass pickeral	15	6	0.5
American eel	10	2	6.3
Sauger	10	2	1.6
Spotted bass *	80	95	33.2
Smallmouth bass	25	9	0.7
Largemouth bass *	60	45	10.2
Warmouth sunfish	30	10	1.9
Green sunfish *	75	44	3.1
Spotted sunfish	25	12	0.8
Longear sunfish *	100	311	23.6
Bluegill sunfish *	90	88	10.7
Hybrid sunfish	15	4	0.2
Rock bass *	80	72	18.4

Table 1 - Continued

Black crappie	45	16	3.8
White crappie	45	21	6.2
Pomixis sp.	10	7	3.7
Freshwater drum	35	10	15.3
Totals		2,064	1,102.1

*Important species

Lower St. Francis (Table 2)

The station is located on the St. Francis River near Qulin (T22N, R8E, Sect. 3, 10, Butler and Dunklin Counties). It is within the area which might be polluted from a factory located in the vicinity of Poplar Bluff and its fish population is representative of this part of the river. The important species include the highest proportion of rough fish and the lowest proportion of game fish of any area discussed here. The fishery is of poor quality.

Lower Current (Table 3)

These samples were taken from Current River just below the town of Doniphan (T23N, R2E, Sect. 34, Ripley County). The fish population should be representative of this portion of the river. A very good quality fishery is indicated. The proportion of rough fish among the important species and the proportion of game species was quite high. Smallmouth bass, largemouth bass, spotted bass, rock bass, channel catfish, and chain pickerel all were included among the important species at this station. This is one of the best fisheries reported here.

Current No. 5 (Table 4)

Current River Station No. 5 is located at Elm Spring near the town of Chilton (T26N, R1E, Sect. 11, Carter County). It is downstream from Van Buren and Big Spring. The fish population indicates it should have a high quality fishery. Among the important species, the proportion of game fish was second highest and the proportion of rough fish second lowest of any station reported here. Smallmouth bass, largemouth bass, chain pickerel, and rock bass all are on the list of important species.

Middle Current (Table 5)

This station is located at Powdermill Ferry (T29N, R2W, Sect. 16, Shannon County). The fish population should be fairly representative of this portion of the stream. It indicates that the fishery should be of high quality. The proportion of game fish among the important species was highest of any area discussed here and the proportion of rough fish was lowest. Smallmouth bass and rock bass are on the list of important species.

Lower Gasconade (Table 6)

This station is located on the Gasconade River near the town of Rich Fountain (T42N, R8W, Sect. 16, Osage County). The diversity of the fish population is characteristic of downstream areas of our streams. The high proportion of game fish among the important species and the relatively low proportion of rough fish are indicative of a fishery of high quality. Smallmouth bass, rock bass, white crappie, and channel catfish were included among the important species.

Middle Gasconade (Table 7)

This location is on the Gasconade River at White House Ferry, near Jerome (T37N, R10W, Sect. 2, Phelps County). The fish population is probably representative of this portion of the stream. A fishery of high quality is indicated by the high proportion of game fish and low proportion of rough fish among the important species. The important species list includes smallmouth bass, largemouth bass, and rock bass.

Table 2. Species taken, with frequency of occurrence, total number and total weight of each in 20 collections from the Lower St. Francis River Station, 1947-1953.

Species	Frequency of Occurrence (per cent)	Number	Weight (pounds)
Shortnose gar *	90	91	86.9
Spotted gar	15	3	2.8
Longnose gar	60	26	56.1
Bowfin	25	9	24.8
Mooneye	5	1	0.2
Goldeye	5	2	0.5
Gizzard shad *	75	334	115.5
Bigmouth buffalo	45	16	44.2
Black buffalo *	40	38	60.4
Smallmouth buffalo *	55	50	108.8
Ictiobus, sp.	10	4	15.4
Blue sucker	30	17	46.2
Northern redhorse	5	1	1.3
Moxostoma, sp.	5	1	0.2
Carp *	100	368	941.5
Channel catfish *	90	163	158.6
Black bullhead	5	4	1.2
Yellow bullhead	5	1	1.3
Flathead catfish *	80	94	140.4
American eel	10	2	2.3
White bass	35	16	3.5
Spotted bass *	50	41	8.3
Smallmouth bass	5	1	0.2
Largemouth bass	30	10	3.6
Warmouth sunfish	30	13	1.7
Green sunfish	20	4	0.3
Orangespotted sunfish	10	3	0.1
Longear sunfish *	55	37	2.1
Blue gill sunfish *	55	40	5.1
Black crappie	30	8	1.3
White crappie *	70	61	15.0
Pomoxis, sp.	10	6	3.5
Freshwater drum *	95	75	67.3
Totals (30 species)		1,540	1,920.6

* Important species

Table 3. Species taken, with frequency of occurrence, total number, and total weight of each, in 21 collections from the Lower Current River Station, 1947-1953.

Species	Frequency of Occurrence (per cent)	Number	Weight (pounds
Longnose gar	19	6	4.38
Bowfin	5	1	5.00
Mooneye	38	14	4.89
Goldeye	5	1	0.28
Skipjack	10	3	1.25
Gizzard shad *	62	255	92.84
Bigmouth buffalo	10	2	8.88
Black buffalo	10	3	8.72
Smallmouth buffalo	24	9	15.77
River carpsucker	24	6	7.28
White sucker	5	1	1.34
Hog sucker *	67	50	20.25
W. Creek chubsucker	10	2	0.50
Spotted sucker	19	11	4.25
Black redhorse *	62	135	95.69
Golden redhorse *	62	192	105.54
Silver redhorse	5	1	0.72
Northern redhorse *	43	34	25.77
River redhorse	5	2	10.13
Redhorse sp.	38	30	12.26
Carp *	29	10	34.03
Hornyhead chub	14	8	0.51
No. Creek chub	5	3	0.34
Common shiner	14	7	1.09
Stoneroller	5	1	0.06
Channel catfish	33	20	44.94
Black bullhead	24	7	2.00
Yellow bullhead	43	14	4.96
Bullhead sp.	10	3	1.56
Flathead catfish *	57	28	221.56
Grass pickerel	10	3	0.97
Chain pickerel	76	50	21.65
American eel	19	6	11.59
White bass	5	1	1.19
Yellow walleye	24	6	10.68

Table 3 - Continued

Spotted bass *	67	53	27.89
Smallmouth bass *	76	64	10.96
Largemouth bass *	90	76	29.63
Warmouth sunfish	57	43	9.45
Green sunfish *	95	123	15.92
Spotted sunfish *	81	67	7.93
Longear sunfish *	100	1,138	109.10
Sunfish sp.	5	1	0.03
Bluegill sunfish *	71	101	17.89
Rock bass *	100	738	193.56
Black crappie	29	9	4.12
White crappie	19	11	5.31
Hybrid sunfish	14	4	0.50
Freshwater drum	24	10	10.78
Sculpin	5	1	0.13
Totals 46 species		3,364	1,226.07

* Important species

Table 4. Species taken, with frequency of occurrence, total number, and total weight in 6 collections from the Current River Station No. 5, 1952-1953.

Species	Frequency of Occurrence (per cent)	number	Weight (pounds)
Mooneye	17	2	0.7
Skipjack	50	3	0.6
Gizzard shad *	83	183	62.7
Blue sucker	17	1	2.6
White sucker	33	7	6.7
Hog sucker *	100	23	14.4
Creek chubsucker	17	1	0.1
Spotted sucker *	83	26	25.8
Black redhouse *	67	75	32.4
Golden redhorse *	100	50	26.4
Silver redhorse	17	1	8.6
Northern redhorse	50	9	7.6
Carp	50	6	25.0
Black bullhead	33	2	1.7
Yellow bullhead *	83	45	42.0
Chain pickerel *	100	61	25.2
American eel	33	3	3.9
Walleye	17	3	7.4
Smallmouth bass *	100	28	12.9
Largemouth bass *	83	49	19.0
Warmouth sunfish *	100	43	13.9
Green sunfish *	100	24	5.8
Spotted sunfish *	100	121	17.0
Longear sunfish *	100	505	58.5
Bluegill sunfish *	67	36	10.9
Redear sunfish	17	1	9.3
Rock bass *	100	454	143.4
Black crappie	50	5	1.9
Totals		1,767	577.4

* Important species

Table 5. Species taken, with frequency of occurrence, total number, and total weight of each, in 21 collections from the Middle Current River Station, 1947-1953.

Species	Frequency of Occurrences (per cent)	Number	Weight (pounds)
Paddlefish	5	1	3.13
Spotted gar	5	1	0.34
Longnose gar	14	4	0.59
Mooneye	10	2	0.62
Goldeye	5	1	0.22
Gizzard shad	48	97	31.08
Smallmouth buffalo	5	2	3.62
White sucker	14	4	3.41
Hog sucker *	81	142	30.59
Black redhorse *	81	149	63.83
Golden redhorse *	57	75	47.46
Northern redhorse	29	16	18.19
River redhorse	5	1	1.47
Redhorse sp.	19	11	3.41
Hornyhead chub	29	18	2.31
No. Creek Chub	10	14	1.41
Common shiner	24	12	0.95
Stoneroller	14	8	0.79
Yellow bullhead	10	2	2.29
Bullhead sp.	10	2	1.69
Flathead catfish *	33	20	121.41
American eel *	67	21	43.85
Yellow walleye	10	2	3.16
Spotted bass	5	3	0.19
Smallmouth bass *	100	171	51.07
Largemouth bass	14	4	1.40
Warmouth sunfish	14	4	0.65
Green sunfish	52	64	9.06
Spotted sunfish	33	14	1.13
Longear sunfish *	95	554	53.04
Bluegill sunfish	29	11	2.72
Sunfish sp.	5	1	0.09

Table 5 - Continued

Rock bass *	100	913	232.92
Black crappie	10	3	1.29
Hybrid sunfish	10	4	1.04
Freshwater drum	10	4	4.37
Sculpin	5	2	0.16
Totals, 33 species		2,357	744.95

Table 6. Species taken, with frequency of occurrence, total number, and total weight of each, in 21 collections from the Lower Gasconade River Station 1947 - 1953.

Species	Frequency of Occurrence (per cent)	Number	Weight (pounds)
Shortnose gar	48	46	24.31
Longnose gar *	71	69	41.91
Mooneye	48	16	5.19
Goldeye	14	10	7.16
Gizzard shad *	86	812	130.28
Bigmouth buffalo	24	6	11.53
Smallmouth buffalo	24	10	33.31
Buffalo sp.	5	1	2.00
Quillback	19	4	4.28
River carpsucker	29	10	10.66
Highfin sucker	19	7	8.84
White sucker	10	3	1.97
Hog sucker *	76	241	70.81
Black redhorse *	52	188	41.38
Golden redhorse *	76	465	152.65
Silver redhorse	33	17	16.53
Northern redhorse *	71	93	45.09
River redhorse	38	21	11.72
Redhorse sp.	48	112	28.38
Carp *	67	55	62.50
Stoneroller	10	4	0.16
Channel catfish *	67	165	247.50
Blue catfish	5	1	1.13
Black bullhead	5	2	0.72
Yellow bullhead	10	2	0.66
Flathead catfish *	43	52	269.40
American eel	10	2	3.22
White base	29	40	6.81
Eastern sauger	14	3	0.94
Walleye	14	8	4.34
Southern Log perch	10	3	0.16
Spotted bass	5	1	0.22
Smallmouth bass *	100	322	95.96
Largemouth bass	62	42	23.66

Table 6 - Continued

Green sunfish *	81	74	12.28
Longear sunfish *	86	451	29.69
Sunfish sp.	10	2	0.31
Bluegill sunfish *	76	58	9.48
Rock bass *	100	264	71.50
Black crappie	62	49	15.22
White crappie *	76	98	28.16
Hybrid sunfish	14	3	0.31
Freshwater drum *	76	141	56.44
Totals		3,973	1,588.72

* Important species

Table 7. Species taken, with frequency of occurrence, total number, and total weight of each, in 21 collections from the Middle Gasconade River Station, 1947 - 1953.

Species	Frequency of Occurrence (per cent)	Number	Weight (pounds)
Shortnose gar	14	4	5.34
Longnose gar	38	20	10.69
Mooneye	52	35	9.50
Goldeye	10	8	0.38
Gizzard shad	57	136	36.19
Bigmouth buffalo	5	1	2.69
River carpsucker	38	8	9.63
Highfin sucker	5	2	2.13
White sucker	5	5	1.19
Hog sucker *	76	226	57.59
Spotted sucker	5	1	0.16
Black redhorse *	71	242	133.06
Golden redhorse *	86	402	189.31
Silver redhorse	19	11	5.34
Northern redhorse *	67	150	87.19
River redhorse	33	23	18.66
Redhorse sp.	33	140	33.75
Carp *	76	108	140.41
Hornyhead chub	14	3	0.47
Northern creek chub	10	1	0.13
Channel catfish	48	24	28.00
Black bullhead	10	3	1.25
Flathead catfish *	43	30	173.41
American eel	14	4	7.91
White bass	5	29	1.09
Eastern sauger	5	1	0.50
Walleye	14	5	3.22
So. Log perch	10	7	0.47
Spotted bass	10	3	0.63
Smallmouth bass *	67	204	55.47
Largemouth bass *	67	36	19.38
Green sunfish *	95	153	17.94
Spotted sunfish	5	1	0.19
Redear sunfish	5	1	0.22
Orangespotted sunfish	5	2	0.13

Table 7 - Continued

Longear sunfish *	100	505	40.72
Bluegill sunfish *	76	54	7.47
Rock bass *	100	1,081	237.86
Black crappie	38	59	20.09
White crappie	33	25	5.03
Hybrid sunfish	5	1	0.03
Freshwater drum	62	94	29.84
Totals		3,848	1,392.66

*Important species

Lower Meramec (Table 8)

This station is located on the Meramec River at Times Beach (T43, 44N, R4E, Sect. 5, 32, St. Louis and Jefferson Counties). It is below the mouth of Big River and so would receive any pollution originating in the Big River watershed. The fish population was very diverse, but indicates a fishery of fairly good quality. The proportion of game fish among the important species was moderately high, the proportion of rough fish was rather low. Smallmouth bass, white crappie, black crappie, and channel catfish were included among the important species.

Middle Meramec (Table 9)

This station is located on the Meramec River near St. Clair (T4IN, RIE, Sect. 7, Franklin County). A fairly good fishery is indicated by the fish population. Among the important species the proportion of game fish was not high, but the proportion of rough fish was fairly low. Smallmouth bass, rock bass, and channel catfish all were important.

Other Streams

We do not have data comparable with that presented above for any portion of Big River. However, other studies show the fish population to be such as would support a fishery of good quality, probably comparable to that of the Gasconade River.

The best information on the fishery of the Mississippi River is contained in "Commercial and Sport Fishes of the Mississippi River from Caruthersville, Missouri, to Dubuque, Iowa" by Barnickol and Starrett (Illinois Natural History Survey Bulletin, Volume 25, Article 5). This shows a low proportion of sport fishes in the section below the mouth of the Missouri River and a high proportion of commercial or rough fish. They point out that pollution, originating chiefly in the St. Louis metropolitan area, has adversely affected the fish population and fishery of this portion of the Mississippi.

Creel Census Data

The Missouri Conservation Commission conducted a statewide creel census from 1946 to 1958. The information was collected by Conservation Agents from fishermen interviewed in the regular course of their duties as enforcement officers. This data was sorted and tabulated by Fisheries Section personnel. It gives fairly reliable information on the rate of success and species composition of the catch. It cannot be used as a basis for comparing the amount of fishing done on various waters, since the amount of material available from a given area depended largely on the interest and activity of the individual agent.

Here is presented (Table 10) the results for seven areas with which we are concerned in this investigation. The location of these areas is shown on the map. The material in the table is based on the total amount of information collected in each area in the 9 years, 1950 to 1958. The totals for the 9 years are presented rather than the annual figures both in the interest of brevity and because this tends to smooth out minor fluctuations in the data.

Table 8. Species taken, with frequency of occurrence, total number, and total weight in 20 collections from the Lower Meramec River Station, 1947 - 1953.

Species	Frequency of Occurrence (per cent)	Number	Weight (Pounds)
Lamprey, sp.	5	1	0.03
Shortnose gar *	70	26	19.97
Spotted gar	5	1	0.16
Longnose gar	55	31	26.64
Mooneye	55	45	7.25
Ohio shad	5	2	0.09
Gizzard shad *	90	455	106.68
Bigmouth Buffalo	15	4	3.13
Black buffalo *	15	4	33.63
Smallmouth buffalo *	45	17	29.59
Ictiobus, sp.			
River carpsucker *	85	75	77.03
Highfin carpsucker	25	7	6.84
Plains carpsucker	5	2	4.56
Blue sucker *	30	18	50.19
Hog sucker *	65	121	45.41
Black redhorse	40	12	4.06
Golden redhorse *	85	182	86.66
Silver redhorse	25	5	16.13
Northern redhorse *	85	224	89.81
River redhorse *	55	41	37.31
Moxostoma sp.	20	23	7.50
Carp *	70	64	92.53
Stoneroller	5	3	0.09
Channel catfish *	95	139	91.09
Black bullhead	10	2	0.91
Yellow bullhead	10	4	2.09
Bullhead sp.	5	1	0.16
Flathead catfish *	90	42	90.78
Grass pickerel	5	1	0.22
American eel	30	8	14.06
White bass	40	20	4.13
Eastern sauger	50	32	14.78
Yellow walleye	40	39	16.50
Northern crystal darter	5	7	0.22

Table 8 - Continued

Smallmouth bass*	90	153	50.24
Largemouth bass	40	20	6.53
Warmouth sunfish	5	1	0.16
Green sunfish	55	54	6.31
Orangespotted sunfish	20	11	0.34
Longear sunfish*	90	552	41.33
Bluegill sunfish	45	35	3.41
Rock bass	60	30	5.38
Black crappie *	80	87	16.25
White crappie *	90	99	19.11
Pomoxis, sp	5	1	0.13
Hybrid sunfish	5	1	0.16
Freshwater drum	100	148	74.73
Totals, 44 species		2,864	1,216.86

* Important species

Table 9. Species taken, with frequency of occurrence, total number, and total weight in 21 collections from the Middle Meramec River Station, 1947 - 1953.

Species	Frequency of Occurrence (per cent)	Number	Weight (pounds)
Shortnose gar	10	2	1.59
Longnose gar	48	17	14.28
Mooneye	57	35	8.47
Skipjack	5	5	0.16
Ohio shad	10	6	0.72
Gizzard shad *	67	236	92.72
Smallmouth buffalo	10	2	6.63
Ictiobus sp.	5	1	2.63
Quillback carpsucker	14	3	5.81
River carpsucker	24	11	8.88
Highfin carpsucker	48	15	15.72
Hog sucker *	81	216	69.86
Black redhorse *	62	312	111.59
Golden redhorse *	86	553	218.78
Silver redhorse	38	23	13.47
Northern redhorse *	86	231	96.38
River redhorse	29	17	26.78
Moxostoma sp	43	209	75.80
Carp *	48	18	36.25
Hornyhead chub	14	4	0.31
Common shiner	19	4	0.28
Stoneroller	14	7	0.25
Channel catfish *	67	85	55.97
Black bullhead	5	1	0.44
Yellow bullhead	14	4	2.47
Flathead catfish *	62	27	88.47
Schilbeodes sp	5	1	0.05
Grass pickerel	5	1	0.06
American eel	33	8	15.38
White bass	14	3	2.28
Yellow walleye	24	9	15.97
Logperch	5	2	0.06
Smallmouth bass *	90	154	37.75
Largemouth bass	43	22	6.53
Warmouth sunfish	5	1	0.13

Table 9 = Continued

Green sunfish *	76	94	9.78
Spotted sunfish	19	4	0.53
Orangespotted sunfish	10	2	0.06
Longear sunfish *	100	1,694	120.28
Bluegill sunfish	43	35	4.44
Rock Bass *	67	211	38.34
Black crappie	48	24	5.94
White Crappie	29	25	6.00
Freshwater drum	62	24	19.75
Sculpin	5	1	0.13
Totals, 42 species		4,359	1,238.18

* Important species

Table 10. Summary of general creel census results for various watersheds for the years 1950 - 1958

Stream	Lower Black	Lower St. Francis	Lower Current	Lower Gasconade	Lower Meramec	Middle Meramec	Big
Trips	1,248	889	1,480	2,873	921	1,543	1,739
Hours fished	3,508	3,307	3,997	9,144	3,301	5,189	5,345
Fish cought	4,050	2,423	5,013	6,839	1,216	2,971	2,881
Fish per hour	1.15	0.73	1.25	0.74	0.37	0.57	0.54
Per cent successful	57	67	74	64	50	53	46
Method used (%)							
Still fishing	79	59	52	57	88	72	70
Casting	18	27	30	13	2	10	17
Other	3	14	17	30	10	18	13
Species caught (%)							
Suckers	4	5	33	25	3	29	19
Green sunfish	24	5	10	15	13	15	17
Other sunfish	29	7	14	8	12	19	19
Rock bass	8	1	17	11	tr	4	10
Carp	2	32	2	12	9	4	2
Smallmouth bass	1	tr	14	7	4	6	13
Channel catfish	2	9	1	7	15	9	10
Drum	1	7	3	8	21	8	1
Crappies	10	20	tr	2	10	2	tr
Largemouth bass	10	2	4	2	1	1	2
Bullheads	8	4	tr	1	4	1	2
Buffalo	tr	4	tr	2	1	tr	tr
Walleye	1	0	1	tr	tr	tr	tr

Lower Black

This area consisted of all flowing waters of Black River watershed in Missouri downstream from Clearwater Dam. It included the Clearwater tailwaters and the portion of the watershed above Poplar Bluff where the fishery is of higher quality than downstream from Poplar Bluff. The creel census indicates a high rate of success and a large proportion of game fish in the catch. Both are considered to be due to the influence of the upstream areas. The fishery below Poplar Bluff is of low quality.

Lower St. Francis

This area consisted of the main stream of the St. Francis River in Missouri below Wappapello Dam. As with the Lower Black, a tailwater fishery is included, and it is believed to have strongly influenced the results of the creel census. Although a relatively high rate of success and a large proportion of game fish in the catch were indicated, these results are not characteristic of the St. Francis in the vicinity of Poplar Bluff and below. The fishery of this part of the river is of low quality.

Lower Current

This area consisted of the streams of that portion of the Current River watershed below the mouth of Jacks Fork. This coincides quite nicely with the portion of the watershed with which we are concerned in this investigation. The rate of fishing success was quite high, and the proportion of game fish in the catch was also high. The percentage of smallmouth bass and rock bass were the highest of any area considered here. These figures would be even higher, but were depressed by the large number of suckers in the catch, most of which were taken by gig. A high quality fishery is indicated.

Lower Gasconade

The streams of that portion of the Gasconade River watershed below the mouth of Big Piney River constituted this area. This is also the portion of the stream which would be most likely to be polluted by pulp mill wastes. The creel census shows a high rate of success and a large proportion of game fish. Much gigging is done in the Gasconade and large numbers of the suckers taken by this method serve to depress the percentages of game fish. A high quality fishery is indicated.

Lower Meramec

The streams of that portion of the watershed of Meramec River below the mouth of Big River made up the lower Meramec area. The area meets many of the requirements for the location of a pulp mill. The rate of fishing success was low, and although the proportion of game fish was high, half of them were channel catfish. A fishery of rather low quality is suggested.

Middle Meramec

This area consisted of the streams of that portion of the Meramec River watershed between the mouth of Big River and the southern boundary of Meramec State Park and not including the watersheds of Big and Bourbeuse Rivers. Fishing success was moderate, and although the proportion of game fish was not high, this figure was depressed by large numbers of suckers taken by gigging. A moderately high quality fishery is indicated.

Big

This area consisted of the streams of the Big River watershed. All headwater and tributary streams are included; therefore, it is not truly representative of the portions of Big River which might be polluted by pulp mill wastes. Fishing success was moderate, and the proportion of game fish in the catch was high. Some suckers taken with the gig were included, so game fish figures are somewhat depressed. A high quality fishery is indicated.

Discussion

Although the information presented here is not strictly up to date, we have no reason to believe that any important changes have occurred in either the fish population or the fishery of most of the streams under consideration. An exception to this is in Current River which has been invaded by carp since 1958. Charles A. Purkett, Jr., of our staff, has shown that these fish were produced in the flooded bottom lands of Arkansas in 1957, that they are a result of a very unusual combination of circumstances, and that they are not prospering in Current River. Management measures have been recommended to help reduce their number. In the meantime they have caused some damage to the fishery by roiling the water and by competition with more desirable species. However, we do not expect them to cause any permanent reduction in the quality of the fishery.

The two sources of information presented are in substantial agreement on the quality of the fisheries furnished by the various streams. In the vicinity of Poplar Bluff and below, the Black and St. Francis rivers support fewer game fish than they do in their upper reaches. This is also true of the Meramec below the mouth of the Big River. We believe, therefore, that these streams would sustain less damage from industrial contamination than other locations considered here. The effect of added industrial contamination on the Mississippi River fishery is hard to assess since this stream already receives contamination from municipal and industrial sources. All of the other streams including the Current, Gasconade, and Big Rivers and the Meramec River above its confluence with Big River support a high or moderately high quality sport fishery which would be seriously impaired by pollution from any source.

APPENDIX IV

TABLE IV - COMPARISON OF FLOW OF STREAMS IN SEVERAL DRAINAGE BASINS OF MISSOURI DURING SEVERE DROUGHT OF AUGUST, 1936*

River	Location	Drainage area sq. mi.	Mean Flow Sec.-ft.	Mean Flow Sec.ft. per sq. mi.	Approx. % of flow derived from large springs
St. Francis**	Patterson	956	11.2	.012	0
Current	Eminence	1,272	405	.318	59
Current	Van Buren	1,667	551	.331	59
Current	Doniphan	2,038	951	.467	62

* Abstracted from table in a Report entitled: "The Large Springs of Missouri", Missouri Geological Survey and Water Resources, Vol. 29, Second Series, p. 33, (1944).

** The report includes a chart comparing the flow of Greer Spring with the flow of the St. Francis River, which shows the discharges for each month during the water year ending September 30, 1936; these data are further compared with the mean discharges October 1922 to 1936. The chart shows that during periods of high flow the discharge of the river is about five times as great as that of the spring, but that during periods of low water, such as August, 1936, it was only about one-tenth as large. The large amount of storage in the underground drainage system of the spring tends strongly to equalize the flow. The discharge of the St. Francis River just below Patterson during this critical low flow month of August, 1936, was largely made up of the flow from Blue (42.3 cfs) and Mill (5.21 cfs) Springs.

Both of these springs are now within the reservoir created by Wappapello Dam.

APPENDIX V

TABLE V - TYPICAL CHEMICAL ANALYSES OF FLOWS FROM LARGE SPRINGS IN RIVER BASINS INCLUDED IN THE PULP & PAPER MILL SITE RECONNAISANCE SURVEY*

River Basin	No.**	Spring	Town	County	Sec.	T.	R.	Flow million gal. per day	Date
Gasconade	32	Boiling	Licking	Texas	24	32N	10W	7.8	8-14-25
	38	Mammoth or Prewett	Edanville	Pulaski	32	34N	10W	11.1	7-21-25
	42	Piney	Yancy Mills	Phelps	4	35N	8W	3.2	6-19-25
	43	Roubidoux or Waynesville	Waynesville	Pulaski	25	36N	12W	(a)	6-11-25
	46	Slabtown	Edanville	Texas	15	33N	10W	8.4	7-21-25
Current	12	Alley	Alley	Shannon	25	29N	5W	57.0	6-19-25
	13	Big	Van Buren	Carter	6	26N	1E	283.0	8-15-25
	15	Montauk	Montauk	Dent	23	32N	7W	(a)	6-19-25
	16	Phillips	Barren	Carter	10	25N	1E	5.7	8-15-25
	18	Round	Owls Bend	Shannon	20	30N	4W	(a)	6-19-25
Black	4	Keener	Keener	Butler	9	26N	5E	12.3	8-3-25
	6	Markham	Williamsville	Wayne	23	27N	4E	4.8	8-1-25
	7	Mill	Mill Spring	Wayne	36	28N	3E	7.0	8-1-25
	9	Reeds	Centerville	Reynolds	28	32N	1E	4.9	7-31-25
	10	Warner Bay	Lesterville	Reynolds	9	31N	2E	10.4	7-31-25
Meramec	58	Blue	Bourbon	Crawford	2	39N	3W	3.2	8-16-25
	59	House	Eureka	St.Louis	4	42N	4E	.5	9-2-25
	61	Kratz	Stanton	Franklin	19	41N	2W	(a)	7-19-25
	63	Meramec	St.James	Phelps	1	37N	6W	73.7	6-27-25
	65	Roaring	Stanton	Franklin	19	41N	1W	.65	9-3-25

*Abstracted from table in a report entitled: "The Large Springs of Missouri", Missouri Geological Survey and Water Resources, Vol. 29, Second Series, pgs. 38,39,40,41, (1944).

No.	Turbidity	Coef. of fineness	Total suspended matter	Vol. suspended matter	Non-vol suspended matter	Total hardness as $CaCO_3$	Alkalinity as $CaCO_3$	Sum of constituents	Residue after ignition	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na)
32	0	...	0.9	0.7	0.2	199.0	187.5	195.4	123.0	6.8	0.30	41.7	23.1	4.2
38	5	0.12	0.6	0.2	0.4	183.1	184.5	180.7	117.0	7.6	1.63	38.3	21.3	0.3
42	5-	0.28	1.4	0.9	0.5	156.1	155.8	166.6	111.0	9.6	0.04	32.1	18.5	5.3
43	..	...	0.4	0.2	0.2	167.3	159.3	164.0	115.0	4.8	0.22	33.3	20.5	5.0
46	5	0.14	0.7	0.3	0.4	144.1	150.8	148.2	101.0	6.6	0.23	30.1	16.8	1.1
12	5-	0.44	2.2	0.9	1.3	150.5	137.4	148.4	114.0	5.4	0.17	30.5	18.1	4.6
13	0	...	0.6	0.3	0.3	192.1	185.0	187.7	109.0	6.0	0.36	39.9	22.5	4.9
15	5-	0.34	1.7	0.6	1.1	151.2	148.0	152.9	98.0	2.4	1.33	31.3	17.8	5.2
16	0	...	1.0	0.3	0.7	188.0	182.7	181.5	113.0	5.4	0.50	39.1	22.0	1.7
18	5-	0.30	1.5	1.1	0.4	165.0	167.0	168.2	134.0	7.2	0.28	33.3	19.9	4.1
4	0	...	0.5	0.2	0.3	163.1	168.6	173.0	140.0	13.8	0.59	33.6	19.3	1.4
6	0	...	2.6	0.6	2.0	176.8	192.1	210.3	171.0	21.2	0.21	38.2	19.8	7.1
7	0	...	0.1	0.1	0.0	169.0	167.7	166.8	114.0	7.8	0.70	34.8	20.0	0.6
9	0	...	0.2	0.2	0.0	114.7	132.7	128.0	68.0	6.2	0.66	23.9	13.4	2.3
10	0	...	1.0	0.6	0.4	133.8	134.5	134.0	84.0	7.4	0.77	27.6	15.8	0.0
58	0	...	26.0	0.0	26.0	163.2	155.5	169.8	101.0	6.6	0.62	35.1	18.4	3.5
59	10	0.12	1.2	0.0	1.2	281.7	248.2	289.4	196.0	9.8	0.62	92.3	12.4	0.0
61	..	...	19.0	0.0	19.0	124.1	118.0	132.7	95.0	8.6	0.23	25.5	14.7	1.4
63	0	...	1.4	0.4	1.0	149.0	147.9	153.2	87.0	6.2	0.87	30.2	17.9	3.3
65	20	0.06	1.3	0.6	0.7	180.2	165.3	185.3	120.0	7.8	0.58	36.5	21.7	1.9

*All samples analyzed were collected during the dry season unless otherwise stated. Figures showing flow of springs indicate that measurements were made the same day the sample was taken. Where the flow was not measured at that time the fact is designated by the letter (a). The analyses were made by H. W. Mundt and W. D. Turner.

No.	Carbonate (CO_3)	Bicarbonate (HCO_3)	Sulphate (SO_4)	Chloride (Cl)	Nitrate (NO_3)	Error, per cent
32	0.0	228.6	3.7	2.6	0.80	3.1
38	2.7	219.3	0.2	1.9	0.39	-1.1
42	4.5	180.7	2.9	3.4	1.29	0.9
43	3.0	188.1	2.0	1.0	1.81	4.2
46	1.5	180.7	1.2	1.4	0.53	-2.5
12	3.6	160.3	1.4	5.0	0.91	4.6
13	0.0	225.2	1.0	2.1	0.31	3.6
15	7.8	165.4	0.2	4.8	2.05	1.7
16	0.0	222.5	1.6	2.1	0.00	1.2
18	6.2	190.9	0.6	2.4	0.53	0.6
4	12.9	179.4	0.0	3.2	0.51	-2.1
6	11.7	210.4	5.3	3.2	0.17	-2.4
7	12.3	179.4	0.0	2.7	0.27	-0.3
9	16.0	129.4	0.0	2.2	0.34	-6.5
10	7.8	148.2	0.2	2.2	0.00	-1.3
58	7.8	173.8	9.0	1.9	1.86	0.4
59	0.0	302.3	19.3	3.6	3.03	1.1
61	3.3	137.0	8.0	2.7	0.98	-1.7
63	8.4	163.1	2.7	2.4	1.73	0.2
65	0.0	201.6	10.5	6.6	1.06	-0.8

Note: All chemical analyses are expressed in parts per million in Table V. The coefficient of fineness is the ratio of the suspended matter to the turbidity and is a measure of a size of the particles in suspension. Total hardness has been calculated as calcium carbonate from determined calcium and magnesium after the magnesium content has been calculated to calcium. Alkalinity has been calculated as calcium carbonate from the carbonate and bi-carbonate radicals. The sum of constituents has been reported rather than the customary "total dissolved solids". It is the equivalent to the latter designation in usual water analysis.

**Numbering conforms to original report; source information and analyses are correlated by these numbers in the several sections of this chart.

APPENDIX VI

TABLE VI - DATA REGARDING MAIN SOURCES OF POLLUTION - BASINS INCLUDED IN PULP & PAPER MILL SITE RECONNAISSANCE STUDY

(Data in 1957 Inventory, Municipal and Industrial Wastes - Cooperative Report, Public Health Service, U.S. Department of Health, Education and Welfare - Revised).

Community, Sewer or Sanitary District, Institution or Industry*	1960 Pop.	Est. Pop. Served	Treatment Facilities			Pop.Equiv. (BOD)
			Des'd for P.E. 1000's Av.Daily Flow MGD	Treatment	Discharge to	Untreated Waste Treated Waste
Gasconade River Drainage Basin (Mr-14)						
Cabool (1)	1,284	1,200	2.0 0.25	Sh,Cp,Ftr,Cp, Dcp,Bo	Big Piney Creek	24,000 17,000
(2)	--	--	1.50 0.15	Lo	Piney River	3,700E 400E
Fort Leonard Wood	10,000+	10,000+	x x	Primary-Secondary Trickling Filter Plant	Big Piney River	-- --
Houston	1,660	400	1.0 0.1	Sc,Ci,Ftr, Cp,Bo	Brushy Creek to Big Piney Creek	400 50
Mountain Grove East	3,176	2,160	2.16 0.216	Lo	Buttermilk & Whetstone Creek	x
West	--	2,420	2.42 0.242	Lo	(Same)	x
Rolla (Vichy Plant)	--	200	1.2 0.12	Sc,Cm,Am, Cm,Dh,Bo	Branch of Spring Cr.	200 20

TABLE VI - Continued

Community, Sewer or Sanitary District, Institution or Industry*	1960 Pop.	Est. Pop. Served	Treatment Facilities: Des'd for P.E. 1000's Av.Daily Flow MGD	Treatment Facilities: Treatment	Treatment Facilities: Discharge To	Pop.Equiv. (BOD) Untreated Waste Treated Waste
Waynesville	2,377	2,200	4.0 0.4	Gh,Sc,Cm, Ftr,Cm,Eh, Dcmr,Bo	Ribidoux Creek	2,300 300
Current River Drainage Basin: (SM5)						
Doniphan	1,421	1,300	-- --	None	Current River	1,300 1,300
Black River Drainage Basin: (SM5)						
Poplar Bluff (1)	15,926	4,000	9.8 0.98	Lo	Ditch to Black R.	4,000 400
(2)	--	4,500	12.2 1.22	Lo	Pike Cr. Ditch to R.	4,500 450
(3)	--	2,000	7.2 0.72	Lo	Pike Cr. Ditch	2,000E 200E
St. Francis Drainage Basin: (SM6)						
Dexter	5,519	5,000	6.0 0.6	Sc,Cm,Ftr, Cp,Dh,Bo	Ditch #81 to St. Francis	6,000 1,000
East Prairie (a)	3,449	3,000	4.00 0.40	Lo	Drainage Ditch	3,000 300
Farmington	3,618	3,600	10.0 1.5	Sc,Cm,Ftr, Cm,Dcfh,Bo	Br.-Wolf Creek	5,600 1,000
Farmington State Hosp. #4	1,700 -3	2,000	2.0 0.288	Sh,O,Cm,Ftr, Cm,Dcp,Bo	St.Francis River	1,000E 200E

TABLE VI - Continued

Community, Sewer or Sanitary District, Institution or Industry*	1960 Pop.	Est. Pop. Served	Treatment Facilities			Pop.Equiv. (BOD)
			Des'd for P.E. 1000's Av.Daily Flow MGD	Treatment	Discharge To	Untreated Waste Treated Waste
Fredricktown	3,484	3,000	5.5	G(Air)Osc, Cm,Ftr,Cm, Dch,Bo	Saline Creek	3,000 450
Hayti (a)	3,700	2,160	1.60 0.16	Sh.Ci,Ftr, Cp,Bo	Drainage Ditch	2,160E 220E
Ironton	1,310	1,300	2.66 0.266	Lo	Br.Stouts Creek	1,300 130
Kennett	9,098	7,000	8.0 0.8	Ci,Ftr,Cm, Bo	Buffalo Ditch	7,000 1,700
Malden	5,007	4,000	7.5 0.75	G, (Air)Sc, Cm,Ftr,Cm, Dch,Bo, O, xd	Dr.Ditch #81	4,000 400
Puxico	743	700	1.00 0.10	Lo	Turkey Cr. -Mingo R.	x x
Senath	7,369	1,000	2.50 0.25	Lo	Drainage Ditch	1,000E 100E
Steele (a)	2,301	1,500	3.00 0.30	Lo	Drainage Ditch	1,500E 150E
Sikeston (a)	13,765	12,000	16.8 1.68	Sc,Ga,Cm, Dfh,Bo	Drainage Ditch	12,000 1,200
Big River Drainage Basin: (UM19 M34)						
Bismark	1,237	995	1.2 0.12	Sh,Ci,Ftr, Bo	Beard Br. Big River	995 250E

(a) To Mississippi River Bottomland Drainage Channels or Ditches.

TABLE VI - Continued

Community, Sewer or Sanitary District, Institution or Industry*	1960 Pop.	Est. Pop. Served	Treatment Facilities: Des'd for P.E. 1000's / Av.Daily Flow MGD	Treatment Facilities: Treatment	Treatment Facilities: Discharge To	Pop.Equiv. (BOD) Untreated Waste / Treated Waste
Flat River	4,515	3,720	6.0 0.60	Sh,Ci,Bo	Flat River	3,720 2,500
Potosi	2,805	2,750	3.50 0.35	Sh,Ci,Ftr, Cm,Bo,Lo	Mine Breton Cr. Mineral Fork	x x
Meramec River Drainage Basin: (UM19)						
Belle	1,016	965	2.00 0.20	Lo	Kline Branch	x x
Bland	654	525	0.8 .08	Sh,Ci,Ftr, Bo	Br. of Dr.Fork	475 150E
Cuba (1)	1,672	1,000	1.00 0.075	Sh,Cp,(Am Cp)Dcp,Bo	Brush Creek	1,000 100
(2)	400	400	0.50 0.05	LO	Brush Creek	400E 50E
Kirkwood (1) Leffingwell	29,421	24,000	9.0 0.9	Gm,Sc,Cm,Aa Cm,Dfh,Bo	Br.Gravois Cr.	x x
(2) Sugar Grove	--	8,000	x x	Sh,Cm,Aa,Cm, Dfh,Bo,Lo	Sugar Cr. to Grandglaize	x x
Owensville	2,379	2,200	4.5 0.45	Lo	Fork of Redoak Creek	2,200 220

TABLE VI - Continued

Community, Sewer or Sanitary District, Institution or Industry*	1960 Pop.	Est. Pop. Served	Treatment Facilities: Des'd for P.E. 1000's Av.Daily Flow MGD	Treatment Facilities: Treatment	Treatment Facilities: Discharge To	Pop.Equiv. (BOD): Untreated Waste Treated Waste
Pacific	2,795	2,000	3.62 0.362	Lo	Meramec River	2,000 200
Rolla (1)	11,132	4,400	5.0 0.5	Ch,Sc,Cm, Ftr,Cm, Dcmr,Bo	Burgher Br. Lt.Dr.Fork Creek	4,400 450
(2)	--	7,500	12.0 1.2	Sg,Cm,Ftr, Cm,Dh,Bo	Love Creek	7,500 750
St. James	2,384	1,200	2.25 .225	Sh,Ci,Ftr, Cp,Bo	Dr.Fork Cr (Robinson Cr.)	1,200E 120E
Salem	3,870	2,800	3.0 0.15	Sh,Ci,Ftr, Cp,Bo	Spring Cr.	2,800 650
Sullivan (1)	4,098	1,230	1.54 0.15	Lo	Br. of Spring Cr.	1,230 120
(2)	--	910	1.11 0.111	Lo	Br.of Spring Cr.	910 90
(3)	--	2,540	1.89 0.189	Lo	Br.of Spring Cr.	1,540 155
Union	3,937	3,800	7.2 0.72	Lo	Bourbeuse River	4,000 400

*Figures given in the 1957 Inventory have been updated to 1960 from State of Missouri reports on basic data furnished through the Kansas City Regional Office VI Public Health Service, U.S. Department of Health, Education and Welfare, by Mr. H.C. Clare: (See following page for further explanatory notes).

TABLE VI - Explanatory notes continued.

Following designation of community, and 1960 population in the first two columns, the estimated total number of people served by the sewer system, is indicated in the third column, and the next column gives the design capacity figures. The top-line entry - P.E. (1000's) is the population equivalent, in thousands, for which the facilities were designed.

The bottom line entry - Average Daily Flow (MGD) - is the flow for which the facilities were designed. The principal treatment devices and methods are identified by capitalized letters and are further described by subsequent lower case letters. In general, the symbols are arranged in the order of sewage flow with sludge treatment symbols following thereafter. Combination units performing more than one function in a single structure are denoted by enclosing the appropriate symbols in parenthesis.

Industrial waste treatment information is incomplete and not included. Municipal sewage treatment facilities are coded as follows: A -- Aeration; Aa -- Activated sludge, diffused air aeration; Ac -- Contact aerators; Am -- Activated sludge, mechanical aeration; B -- Sludge beds; Bo -- open; C -- Settling tanks; Ci -- two story (Imhoff); Cm -- mechanically equipped; Cp -- plain, hopper bottom or intermittently drained for cleaning; D -- Digester, separate sludge; Dc -- with cover (fixed if not otherwise specified); Df -- with floating cover; Dh -- gas used in heating; Dm -- stirring mechanism; Dp -- unheated; Dr -- heated; E -- Chlorination; Eh -- by hypochlorite; F -- Filters; Ftr -- rotary distributor, standard capacity; G -- Grit chambers; Ga -- aerated grit chamber; Gh -- without continuous removal mechanism; Gm -- with continuous removal mechanism; H -- Sludge storage tanks (not second stage digestion units); L -- Lagoons; Lo -- oxidation lagoons or ponds; ⊕ -- liquid sludge; O -- Grease removal or skimming tanks - not incidental to settling tanks; S -- Screens; Sc -- comminutor (screenings ground in sewage stream); Sg -- screenings ground in separate grinder and returned to sewage flow; Sh -- bar rack (1"2" openings) hand cleaned; X -- Sludge disposal; Xd -- used for fertilizer.

The above information along with other pertinent data will appear in the next published Inventory according to Mr. R.S. Green, Chief, Basic Data Branch, Division of Water Supply and Pollution Control, Public Health Service, U.S. Department of Health, Education and Welfare, Washington, D.C.

APPENDIX VII

TABLE VII - SANITARY ANALYSES OF GASCONADE RIVER WATER ABOVE (0.2 Miles) JUNCTION WITH MISSOURI RIVER*

Date 1950	Ave. Disch. c.f.s.	Temp. °C	Dissolved Oxygen p.p.m.	Dissolved Oxygen % Sat.	5 Day B.O.D. p.p.m.	pH	Alkalinity p.p.m.
Jan.18	23,000	6	11.2	90	0.8	7.9	85
Jan.25	5,000	12	10.1	93	0.7	7.8	116
Feb. 1	3,700	4	12.3	94	0.8	7.8	140
Feb. 8	2,700	8	11.3	95	1.0	7.7	149
Feb.15 2:30 p	10,500	2	11.0	79	1.1	7.7	134
Mar.15 3:10 p	8,000	6	12.0	96	1.1	7.9	122
Apr.12 1:40 p	5,500	11	9.7	88	1.3	-	128
May 10 1:40 p	4,000	18	8.6	90	1.2	8.2	137
Jun.14 1:35 p	14,500	23	7.0	81	1.1	7.8	93
Jul.12 1:45 p	1,700	26	8.1	99	0.6	8.2	154
Aug.16 1:00 p	2,000	25	6.6	79	1.1	7.8	132
Sept.13 11:50 p	1,360	21	8.1	90	2.2	8.2	156
Sept.20 1:00 p	1,170	24	7.9	93	1.1	8.4	161
Sept.27 1:00 p	1,030	19	9.0	96	0.9	8.4	161
Oct.4 1:45 p	940	20	8.3	91	1.2	8.4	159
Oct.11 1:10 p	1,060	17	9.5	98	1.1	8.0	166
Oct.18 12:55 p	900	20	8.9	97	1.4	8.4	173
Nov. 15 12:55 p	840	9	12.5	108	0.9	8.4	176
Dec. 13 1:40 p	880	2	14.4	104	0.8	8.2	185

*See page 3 for explanatory notes.

TABLE VII - Continued

SANITARY ANALYSES OF MISSOURI RIVER WATER BELOW MOUTH OF GASCONADE RIVER

Date 1950	Ave. Disch. c.f.s.	Temp. °C	Dissolved Oxygen		5 Day B.O.D. p.p.m.	pH	Alkalinity p.p.m.
			p.p.m.	% Sat.			
Feb. 8	36,600	5	11.8	92	2.0	8.0	223
Feb.15 1:50 p	110,000	2	11.1	80	4.0	7.5	137
Mar.15 2:25 p	60,000	2	11.5	83	4.3	7.6	122
Apr.12 1:00 p	128,000	8	9.9	83	3.7	--	116
May 10 1:00 p	89,500	16	8.3	83	4.4	7.9	131
Jun.14 1:00 p	115,000	23	7.1	82	2.7	8.0	112
Jul.12 12:55 p	91,000	24	7.1	83	1.5	7.8	122
Aug.16 12:25 p	242,000	24	5.2	61	2.6	7.4	100
Sep.13 1:00 p	64,500	22	7.5	85	2.5	8.0	137
Sep.20 12:20 p	59,200	23	7.5	86	2.5	8.2	151
Sep.27 12:15 p	76,200	19	7.6	81	3.0	8.2	151
Oct. 4 12:55 p	82,500	18	8.1	85	2.6	7.8	127
Oct.11 12:10 p	83,000	15	8.4	83	2.8	7.7	115
Oct.18 12:10 p	59,200	18	8.5	89	2.1	8.1	151
Nov.15 12:15 p	62,500	8	11.1	94	2.9	8.0	161
Dec.13 12:30 p	19,300	2	12.7	92	1.2	8.1	207

*See following page for explanatory note.

TABLE VII - Explanatory note.

*Source: Report: "Lower Missouri River Basin Water Pollution Investigation - A Cooperative State-Federal Report on Water Pollution, 1952" : Public Health Service Publication No. 269, pp. 186-187, (1952) : Gasconade River joins Missouri River 103.5 miles above the mouth of the latter stream at the Mississippi River : Bacteriological results, not given above show very good sanitary quality of Gasconade River at Sampling Station : Further analyses with last sample listed above show total solids - 249 ppm, Ammonia Nitrogen - 0.25 ppm, Nitrite - 0.004 ppm, Nitrate - 0.24 ppm and Chlorides - 28 ppm.

APPENDIX VIII

TABLE VIII - SUMMARY OF LOW FLOW DISCHARGE DATA FOR STREAMS INCLUDED IN PULP AND PAPER MILL SITE RECONNAISANCE SURVEY IN SOUTHEASTERN MISSOURI.

River and Stream Gaging Station	Drainage Area in Square Miles	Lowest Mean Discharge for 7 Consecutive Days* c.f.s.	Minimum Discharge for Period of Record c.f.s.
Gasconade River:			
Jerome	2,840	266	254 Sept.21-22, 1956
Rich Fountain	3,180	282	271 Sept. 19, 1954
Current River:			
Eminence	1,272	334	324 Oct. 7-8, 1956
Van Buren	1,667	479	473 Oct. 7-8, 1956
Doniphan	2,038	852	852 Oct. 8-19, 1956
Black River:			
Leeper	957	147 (b)	133 Aug.11, 1934 (a) 70 Nov.5-6, 1960 (bb)
Poplar Bluff	1,245	249 (b)	236 Aug.12, 1944 (a) 241 Oct. 2, 1956 (b)
St.Francis River:			
Wappapello	1,311	32 (b)	0 June 2, 1952 (b)
Big River:**			
DeSoto	718	26.4	20 Sept. 19, 1954
Meramec River:			
Steelville	781	78.4	74 July 22, 1934
Sullivan	1,475	133	131 Sept.20,22, 1956
Eureka	3,783	209	196 Aug. 27,31; Sept. 1, 1936
Mississippi River:			
St.Louis, Mo.	701,000	28185.7 (c)	27,600 Dec. 13, 1937 ('28-'59)

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*See following page for explanatory notes.

TABLE VIII - Explanatory Notes.

*Source: U.S.G.S. Surface Water Supply Records; discharges are for water year beginning April 1; covers 20 or more years, with data for periods with and without flow regulation being designated.

** Tributary to Meramec River:

(a) No flow regulation

(b) With flow regulation

(bb) Gates of Clearwater Reservoir Dam were closed

NOTE: Clearwater Reservoir storage began June 3, 1948, reached conservation pool level July 4, 1948.

Wappapello Reservoir storage began July 10, 1940, river began to flow through outlet structure July 24, 1940.

(c) Data is for low winter flow period. Records indicate that for the months of July and August a consecutive 7 day minimum flow of 50,000 cfs will occur once in 10 years. River water temperature records are available for this gaging station, the most recent consulted being those for 1959 presented in USGS Water Supply Paper 1643. Flow and temperature data was used for Mississippi River studies from St. Louis to the junction with the Ohio River at Cairo, Illinois, just below the Birds Point Area in Missouri. Memphis, Tennessee Gaging Station records consulted indicate combined flows of the Mississippi and Ohio Rivers, available for effluent assimilation in the vicinity of New Madrid, Missouri.

APPENDIX IX

TABLE IX-A - LOWEST MEAN DISCHARGE OCCURRING ANNUALLY IN THE GASCONADE RIVER AT JEROME, MISSOURI FOR THE INDICATED NUMBER OF CONSECUTIVE DAYS - FOR DESIGNATED SUCCESSIVE YEARS - CFS*

	Lowest Mean Discharge for Following Number of Days**					
YEAR	1	3	7	14	30	60
1923	480.0	480.0	480.0	497.0	507.0	562.0
1924	670.0	670.0	670.0	676.0	729.0	831.0
1925	400.0	406.0	416.0	422.0	440.0	491.0
1926	426.0	426.0	432.0	443.0	453.0	514.0
1927	850.0	867.0	900.0	971.0	1210.0	2110.0
1928	680.0	680.0	680.0	680.0	685.0	691.0
1929	630.0	643.0	664.0	674.0	711.0	866.0
1930	420.0	425.0	430.0	445.0	471.0	491.0
1931	441.0	441.0	446.0	454.0	497.0	545.0
1932	338.0	342.0	348.0	350.0	379.0	431.0
1933	442.0	455.0	470.0	489.0	545.0	600.0
1934	298.0	298.0	299.0	304.0	312.0	366.0
1935	550.0	550.0	561.0	588.0	599.0	657.0
1936	303.0	303.0	307.0	316.0	324.0	364.0
1937	357.0	360.0	385.0	391.0	398.0	419.0
1938	425.0	425.0	425.0	430.0	469.0	521.0
1939	459.0	462.0	467.0	472.0	483.0	496.0
1940	425.0	425.0	431.0	440.0	449.0	461.0
1941	390.0	395.0	403.0	427.0	489.0	563.0
1942	574.0	581.0	588.0	590.0	605.0	782.0
1943	520.0	520.0	523.0	545.0	570.0	593.0
1944	452.0	457.0	469.0	490.0	509.0	627.0
1945	545.0	559.0	576.0	603.0	661.0	824.0
1946	571.0	583.0	607.0	648.0	692.0	819.0
1947	359.0	565.0	588.0	628.0	645.0	689.0
1948	496.0	502.0	511.0	515.0	536.0	565.0
1949	880.0	920.0	1010.0	1070.0	1160.0	1570.0
1950	639.0	645.0	648.0	660.0	681.0	721.0
1951	1270.0	1320.0	1460.0	1840.0	1920.0	2640.0
1952	558.0	558.0	566.0	568.0	579.0	584.0
1953	365.0	365.0	372.0	378.0	390.0	405.0
1954	281.0	286.0	290.0	295.0	302.0	322.0
1955	292.0	294.0	299.0	309.0	329.0	379.0
1956	259.0	261.0	266.0	275.0	278.0	287.0

*Data is for water year beginning April 1, for the period indicated -as low flows usually occur in the late Summer and Fall months.

**Lowest discharge of record - 254 cfs (Sept. 21-22, 1956)

TABLE IX-B - LOWEST MEAN DISCHARGE OCCURRING ANNUALLY IN THE GASCONADE RIVER NEAR RICH FOUNTAIN, MO. FOR THE INDICATED NUMBER OF CONSECUTIVE DAYS - FOR DESIGNATED SUCCESSIVE YEARS - CFS*

	Lowest Mean Discharge for Following Number of Days**					
YEAR	1	3	7	14	30	60
1922	410.0	422.0	435.0	453.0	481.0	531.0
1923	508.0	508.0	513.0	533.0	548.0	618.0
1924	642.0	667.0	669.0	687.0	762.0	879.0
1925	415.0	425.0	436.0	440.0	454.0	542.0
1926	445.0	465.0	471.0	482.0	511.0	583.0
1927	908.0	908.0	921.0	1000.0	1350.0	2480.0
1928	710.0	710.0	710.0	710.0	714.0	719.0
1929	710.0	710.0	720.0	735.0	777.0	973.0
1930	435.0	435.0	454.0	461.0	490.0	532.0
1931	500.0	510.0	517.0	534.0	608.0	675.0
1932	404.0	404.0	412.0	419.0	481.0	536.0
1933	476.0	476.0	488.0	528.0	609.0	679.0
1934	276.0	278.0	284.0	298.0	340.0	412.0
1935	560.0	570.0	577.0	603.0	631.0	679.0
1936	295.0	295.0	304.0	309.0	334.0	390.0
1937	382.0	382.0	384.0	392.0	411.0	436.0
1938	460.0	462.0	466.0	485.0	523.0	595.0
1939	460.0	467.0	481.0	496.0	498.0	507.0
1940	470.0	473.0	477.0	478.0	492.0	509.0
1941	467.0	471.0	476.0	496.0	535.0	591.0
1942	607.0	612.0	618.0	622.0	643.0	843.0
1943	551.0	551.0	554.0	574.0	596.0	625.0
1944	457.0	465.0	500.0	526.0	554.0	732.0
1945	576.0	587.0	608.0	649.0	727.0	935.0
1946	598.0	609.0	633.0	675.0	704.0	878.0
1947	591.0	598.0	615.0	638.0	665.0	708.0
1948	530.0	530.0	531.0	538.0	562.0	596.0
1949	980.0	1010.0	1130.0	1180.0	1270.0	1790.0
1950	732.0	732.0	732.0	740.0	764.0	817.0
1951	1560.0	1600.0	1730.0	2150.0	2260.0	3070.0
1952	575.0	580.0	588.0	590.0	598.0	608.0
1953	370.0	372.0	377.0	382.0	397.0	423.0
1954	275.0	278.0	280.0	282.0	295.0	335.0
1955	322.0	322.0	325.0	341.0	374.0	386.0
1956	277.0	277.0	279.0	281.0	284.0	299.0
1957	427.0	427.0	433.0	445.0	472.0	511.0
1958	595.0	603.0	609.0	620.0	684.0	891.0

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*See following page for explanatory notes.

TABLE IX-B - Explanatory notes.

*Data is for water year beginning April 1, for the period indicated -as low flows usually occur in the late Summer and Fall months.

** Lowest discharge of record - 271 cfs (September 19, 1954).

APPENDIX X

PULP AND PAPER MILL WASTES TREATMENT BY THE ACTIVATED SLUDGE PROCESS

A pulp and paper mill waste treatment system using the activated sludge process was placed in operation in 1955 at Covington, Virginia, by the West Virginia Pulp and Paper Company. This treatment system was specifically designed for mill wastes. Except normal sanitary contributions by mill personnel, the plant treats combined pulp and paper mill effluents as required. This installation along with allied studies, provided much basic information relative to the adaptability of the process in treating wastes originating in the pulp and paper industry.

From experience gained at the Covington Mill, the Company could proceed with confidence in a project at Westernport, Maryland, involving treatment of their nearby Luke Mill wastes along with domestic sewage from Westernport and Luke, Maryland, and Piedmont, West Virginia. Exemplifying cooperation between Government and industry, the 1957 Maryland Legislature authorized the Upper Potomac River Commission, a public corporation, to build and operate a sewage and waste treatment plant. This 21 MGD plant was placed in operation during March 1960, and has been operated since as an industrial waste treatment system pending completion of connecting sewers for the sewage from the three adjoining municipalities.

Information regarding the contract between the Commission and the Company will be found in an article by Hazen*. The mill was enabled to expand production within limits of treatment capacity provided by the Commission, which in turn, is related to critical low flows in the Potomac River. The mill wastes will constitute about 95% of the flow.** The contract with the communities specified waste flow limits set high enough to permit doubling their existing populations, now totaling 6,543 (1960 census).

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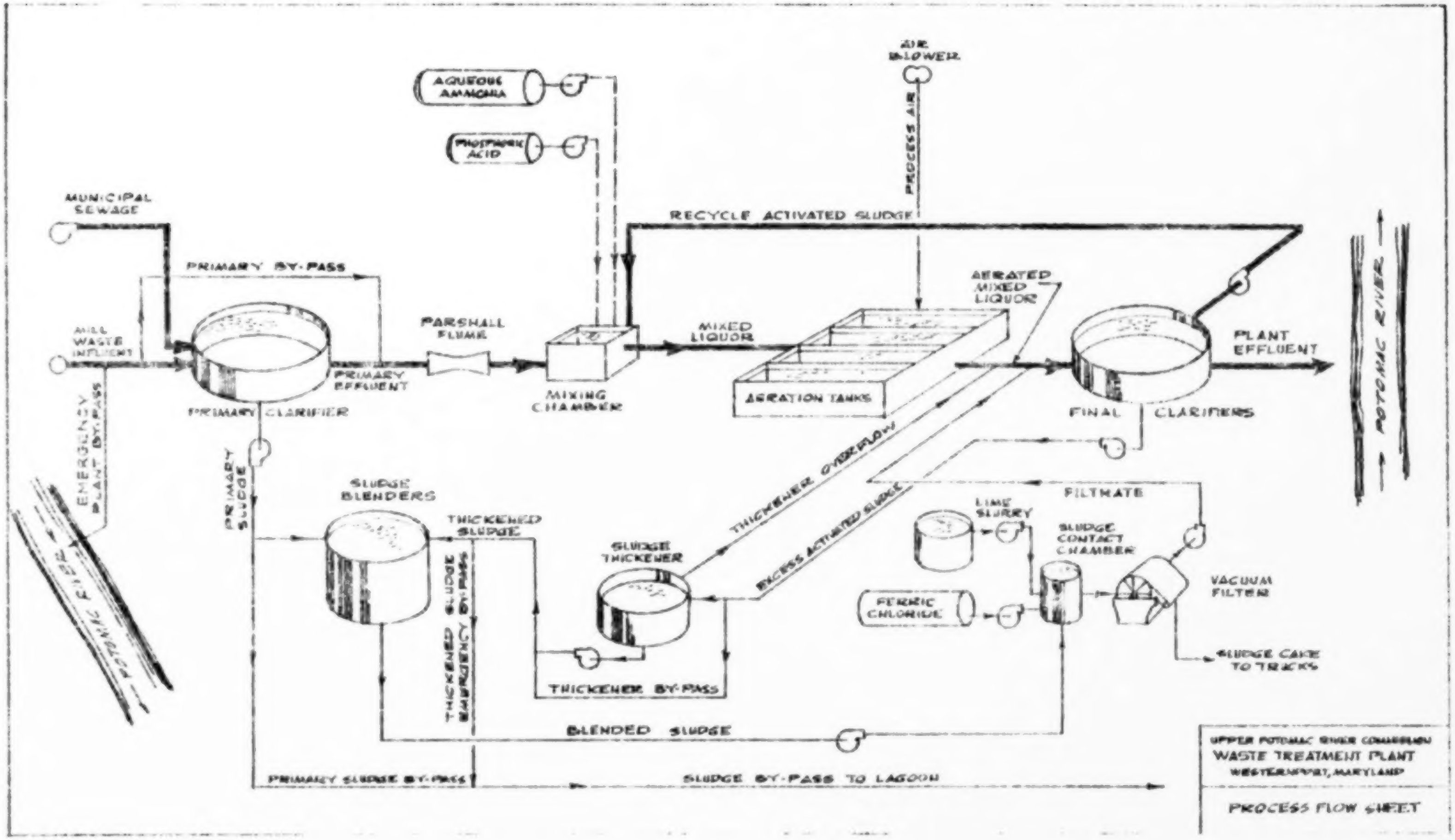
*Hazen, Richard, "Community Treatment Plant for Upper Potomac River", Jour. Water Pollution Control Federation, Vol. 36, No. 6, pp. 640-645, (June 1960).

**Anticipated combined sewage and mill waste flow to the plant.

The attached flow diagram of the treatment system illustrates present equipment and operation. The process employed has a 140 ft. diameter primary clarifier, followed in line of flow by a mixing chamber; four rectangular, 275x44x17 ft. aeration tanks, each equipped with five turbine aerators; two 140 ft. diameter secondary settling tanks, with facilities for recycling sludge to the mixing chamber; and a diffuser in the river for the effluent. Equipment for adding chemical nutrients to the wastes and a system for dewatering excess sludge using a vacuum filter are provided. Chemical nutrients, anhydrous ammonia and phosphoric acid, are added in the mixing chamber to make up for deficiencies in nitrogen and phosphorus in pulp and paper mill wastes. They are needed for developing and maintaining satisfactory biological growths in the sludge recycled in the process. A plant control laboratory along with modern instrumentation facilitate efficient operation of this $4 million plant.

Primary clarifier performance with mill wastes, with average detention time for the wastes at 2.8 hours and an average overflow rate of 785 gallons per square ft. per day, produces from 40% B.O.D. removal at 400 ppm. suspended solids loadings up to 60% B.O.D. removals at about 1800 ppm. suspended solids loadings. The proper operation of this primary treatment unit is reported to exert considerable influence on plant operating costs. The activated sludge system is further reported to reduce the suspended solids 77% or by 55 tons per day and to reduce the B.O.D. 87% or by 15 tons per day. Nutrients required for the wastes amount to about 7 pounds of ammonia and 0.3 pounds of phosphoric acid per 100 pounds of B.O.D. removed. Aeration is aimed at maintaining at least one ppm. dissolved oxygen in the aerator effluent. The plant operates at a pH close to 7. Flexibility to meet fluctuations in loadings has been provided in the design of the plant. Activated sludge, for instance, can be recycled at rates in excess of 100% of the influent. Sludge removed by the treatment process, after dewatering, is disposed of as fill material.


AIR BLOWER
AQUEOUS AMMONIA
PHOSPHORIC ACID
PROCESS AIR
MUNICIPAL SEWAGE
RECYCLE ACTIVATED SLUDGE
PRIMARY BY-PASS
AERATED MIXED LIQUOR
MILL WASTE INFLUENT
PARSHALL FLUME
MIXED LIQUOR
PLANT EFFLUENT
POTOMAC RIVER
PRIMARY EFFLUENT
PRIMARY CLARIFIER
MIXING CHAMBER
AERATION TANKS
FINAL CLARIFIERS
EMERGENCY PLANT BY-PASS
PRIMARY SLUDGE
THICKENER OVERFLOW
EXCESS ACTIVATED SLUDGE
FILTRATE
SLUDGE BLENDERS
THICKENED SLUDGE
LIME SLURRY
SLUDGE CONTACT CHAMBER
SLUDGE THICKENER
VACUUM FILTER
POTOMAC RIVER
FERRIC CHLORIDE
THICKENED SLUDGE EMERGENCY BY-PASS
SLUDGE CAKE TO TRUCKS
THICKENER BY-PASS
BLENDED SLUDGE
PRIMARY SLUDGE BY-PASS
SLUDGE BY-PASS TO LAGOON

UPPER POTOMAC RIVER COMMISSION
WASTE TREATMENT PLANT
WESTERNPORT, MARYLAND

PROCESS FLOW SHEET